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CONTENTS

1. K n u t D a h l: A Review of Recent Salmon Marking Experiments in Norway 3

2. W. J. M. M e n z i e s: Some Preliminary Observations on the Migrations of Salmon (*Salmo salar*) on the Coasts of Scotland 17

1

A REVIEW OF RECENT SALMON MARKING EXPERIMENTS IN NORWAY.

BY

KNUT DAHL.

IN the years 1935, 1936, and 1937 my assistant and collaborator cand. real. Sven Sømme cooperated with me in marking clean salmon in various localities of the coast of Norway. The results for 1935 and 1936 have been published in the papers of the Academy of Science in Oslo, and the report for 1937 is at present in the press[1]).

In the first of these papers we discussed at some length the history of salmon marking, its purposes and results. For the details of this discussion the reader is referred to the paper in question and I intend here only shortly to touch on the main points in the development of salmon marking.

If we omit the earliest, primitive marking experiments we may say that the first systematic marking of salmon was the kelt marking, which was done almost contemporaneously in Norway and Scotland in the end of the 'nineties of the last century by Mr. A. Landmark and Mr. W. Archer.

The main object of this kelt marking was to study the homing instinct of salmon. The conceptions relating to this instinct are of old standing and originally arose as an explanation of the fact that various salmon rivers have peculiar and constant types or, as it were, races of salmon, a fact which after the introduction of the scale method in the first decade of this century has been amply confirmed by a long series of researches on salmon from various rivers in Norway, Great Britain, Iceland, Russia, Sweden, Finland, and Canada.

The next step was the marking of migrating smolts, and in Calderwood's Tay experiments, Dahl's smolt marking in the Os River in western Norway and Alm's marking experiments with smolts in the Indal and Ångerman Rivers in the Baltic, it was well established that the migrating smolts scatter widely over great stretches of ocean, and also that in every known case of recapture they have returned to their native river.

These results made it clear that is was of grea importance to mark clean salmon in the sea i various localities.

Such marking was first done by Mr. A. Land mark in Norway, who also marked clean salmo in the island belt on the west coast of Norway i the same years as kelt were marked in the 'ninetie of last century. But these experiments were not o a scale large enough to yield very decided results although they have now become of value.

Clean salmon were first marked on a large scal under the leadership of Mr. W. L. Calderwoo in Scotland, marking having been performed i 1913—15 and 1920—21. These experiments gav recaptures varying from 9 % to 38 %, far highe than in any kelt marking operations, and a rang of migrations that in many respects resembled tha exhibited in the old kelt experiments. Just as th kelt marking in Norway and Scotland gave n indication of salmon crossing between the tw countries, so the experiments with clean salmo yielded not a single instance of salmon crossin the North Sea.

In 1934, when Mr. Sømme and I planned our present researches into the migrations o salmon, we were struck by the fact that all previous salmon marking experiments had been made with comparatively small marks only provided with a cryptic number. Our idea, however, was that better results would probably be gained by using large and easily visible silver marks, large enough to hold the address of the marker besides the identification number.

In our experimental work in 1935 we accordingly used marks developed on this principle, the natural size of which and mode of attachment to the fish will be seen in Fig. 1.

In 1935 we marked 209 salmon and grilse a two stations situated on the open coasts of western and north-western Norway.

A full list of the experiments and their results has been published in our 1936 paper, where the results have also been discussed in detail. In this review we intend only to give prominence to the main features of these results.

[1]) Knut Dahl and Sven Sømme: Experiments in Salmon Marking in Norway 1935. Oslo, 1936.
— Salmon Markings in Norway 1936. Oslo, 1937.
— Salmon Markings in Norway 1937. Oslo, 1938.

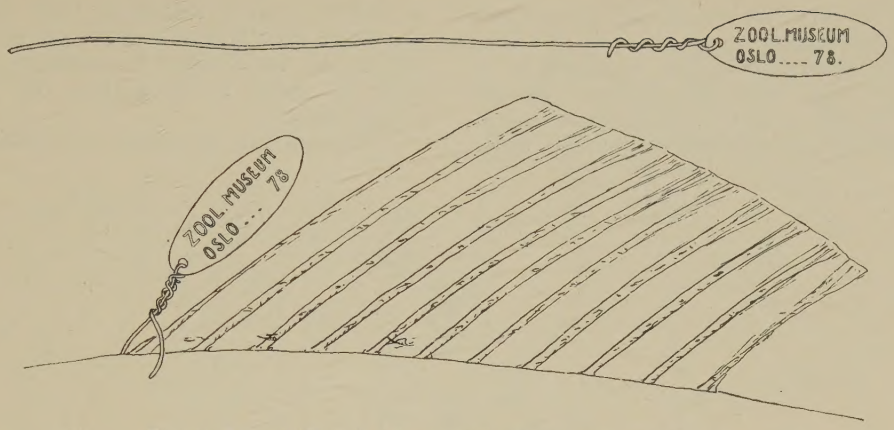


Fig. 1. Dorsal Fin of Salmon with Mark attached. Nat. size.
(From Dahl and Sømme, 1936).

1) The first point in these results to strike one the high percentage of recaptures. Of the 209 h marked no less than 99 fish were retaken, ing a percentage recapture as high as 47·3 %; other words, almost every second fish was aken. This is a rate of recapture far exceeding y previously known figures in salmon marking, d speaks strongly in favour of the new mark ntaining the address.

2) The second remarkable feature about these ults is the range of the migrations. The charts Figs. 2 and 3 show the lines of migration, drawn m the marking station to the position of apture.

From these charts it is easily observed that hough a great number of recaptures occur in rds and rivers not very distant from the marking tion, many fish travel very far, and it is open to stion whether the fish retaken on the coast uld not have travelled far greater distances if y had not been intercepted.

The tremendous extent of the migrations, which exceeds all previous conceptions and marking ords, is amply illustrated by the fact that of 20 fish retaken from the marking at Rong and llandet no less than 2 (10 %) travelled as far Scotland and the south of Sweden, being the st marked fish that have been proved to cross North Sea from Norway to Scotland, and the agerak and Kattegat from Norway to Sweden.

The Titran experiments are also specially rkable for the extremely long distances some the fish travelled, the range of migrations from s station extending from Oslo Fiord to the River g in the Gulf of Onega in the White Sea, wing a range of migration of more than 3600 metres.

The results proved for the first time that salmon migrate between the waters of various countries jacent to the Barents Sea.

3) The idea prevalent in the old days and still current among some authors that salmon do not travel very far from their native rivers was of course invalidated by the earlier smolt marking experiments. But our 1935 results show clearly the erroneousness of the assumption that salmon are restricted in their sea migrations to areas of ocean or sea in the vicinity of, or under the hydrographic or topographic influence of, their native rivers and their estuaries. Their feeding areas in the sea are obviously far larger, and some of them have enormous distances to travel in order to reach their native river.

One part of the mechanism which assists them in performing these homing migrations is demonstrated by our 1935 observations. It is the speed at which salmon are able to travel. Many of the fish apparently go at a leisurely speed, but in the case of fish which have long distances to cover we find a rate of travel which far exceeds all previous records. The chart in Fig. 4 illustrates this feature very clearly.

For instance, the Titran fish which went to the Oslo Fiord covered 1100 km. in 11 days travelling at least 100 km. a day. The fish from the same marking station, which was recaptured in the Wyg River, White Sea, spent 52 days at large and covered 2500 km., travelling at a speed of at least 48 km. per day.

These facts show that however far a salmon may have migrated from its native river during its period of sea feeding, it possesses a capacity for speed which will enable it to reach its home in a surprisingly short time.

4) The results give no support to the idea that the migrations of salmon are largely influenced by environmental factors such as hydrographical changes or ocean currents. On the contrary, the recaptures show that the fish have migrated towards their goal regardless of the various hydrographic changes and current systems which they must have encountered on their way.

The results of this first experiment encouraged us to undertake further research and marking operations. An extension of the experiments to other parts of the coast of Norway seemed necessary, and it also appeared desirable to repeat the experiments at our original stations in order to study possible variations from year to year i the trend of migration and the percentage recaptur Above all we deemed it necessary to mark mor fish in order to strengthen the value of ou observations.

Through the generosity of certain foundation

Fig. 2. Chart showing Migrations of Salmon marked at Rong and Bulandet 1935. (From Dahl and Sømme, 1936).

Fig. 3. Chart showing Migrations of Salmon marked at Titran 1935.
(From Dahl and Sømme, 1936).

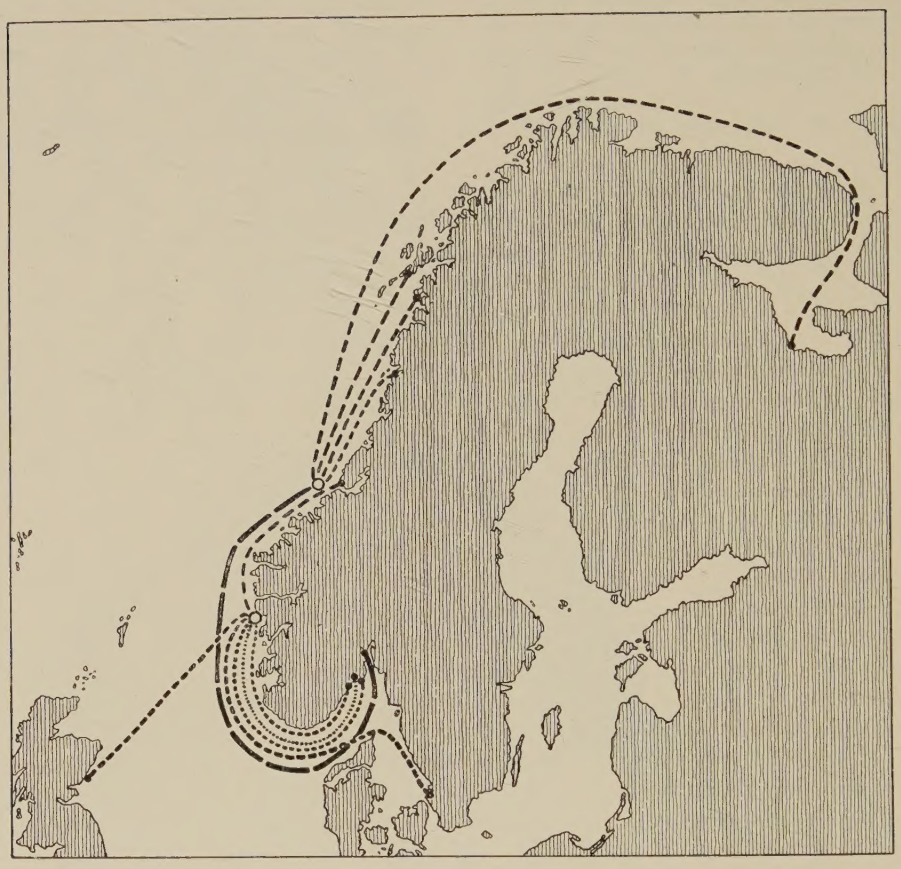


Fig. 4. Chart of the whole Area of Migration of Recaptured Fish showing some of the most extraordinary Migrations (exceeding 400 km.) Number of days at liberty indicated by breaks in the lines. (From D a h l and S ø m m e, 1936).

concerned with marine and salmon research we have been able to continue our marking operations in both 1936 and 1937 and may hope to continue them for some years to come.

In 1936 we retained our old stations at Rong and Titran and added a new station, Melvær, on the Island of Bulandet, a little north of the mouth of the Sognefiord. A couple of smaller stations inside the island belt were established, at Stavøy at the mouth of the Trondheim Fiord, and at Boge in the entrance to the Sørfiord near Bergen.

The results of these experiments are discussed in detail in our papers published in 1937 and 1938, and in the present paper I intend only to draw attention to the main features of these results.

In 1936 we marked altogether 505 Salmon and grilse, of which 241 were recaptured, yielding a percentage recapture of 47·7 %, which compares very well with the 1935 percentage of 47·3 %.

As regards the range of migrations, the results were very similar to those of 1935, though the extreme distances from the marking stations to the places at which the fish were retaken were less than in 1935. The distribution of the recaptures is roughly represented in the following table, for the three main stations.

Number of Recaptures.

Station	Romsdal—Trondheim Area	Hordaland—Sogn Area	Northern Norway	Southern and eastern Norway	Sweden	Scotland	Total
Titran	47	4	3	2	—	1	57
Melvær	9	77	—	8	3	1	98
Rong	11	49	—	5	1	—	66

Titran is situated in the Romsdal—Trondheim area, Melvær and Rong in the Hordaland—Sogn area, and as will be seen from the figures the bulk of the recaptures from the various stations have been made in the fiords and rivers of the respective areas. A number of long migrations occurred, however, and it is interesting to note the long migrations of 400 km. or more shown in Fig. 5.

Fig. 5. Chart of the whole Area of Migration of Recaptured Salmon 1936 showing Migrations of 400 km. or more. (From Dahl and Sømme).

Except that there were no recaptures in northern ussia the results resemble those of 1935.

A very interesting point was etablished in 1936. happened twice that fish marked at Melvær were taken in the nets employed at the marking station Rong. Both these fish were merely examined d again liberated with the same mark attached. ey were both recaptured and the curious and teresting routes followed by them are depicted Fig. 6.

The fish which made the longer journey was arked on 14th June, retaken and liberated on th June and finally recaptured on 4th July. The er was marked on 21st June, retaken and erated on 4th July and finally recaptured on July. What these fish could do in less than weeks is a good instance of the fact that migrating salmon do not necessarily take the shortest path towards their goal.

Another important fact is borne out, as far as the material goes, by our marking experiments inside the island belt at the mouth of fiords. These were not on a very large scale, but still give useful information. This point is exemplified in Fig. 7.

18 fish were marked at this station on 20th to 22nd June 1936 and of these 9 were recaptured. With one exception all the recaptured fish made straight for the Trondheim Fiord and its rivers, which obviously suggests that when the fish have reached the inside of the island belt and approach the fiord mouths they are near the end of their migration. We find a great dissimilarity in the general trend of the migrations as compared with the charts from the coastal marking experiments.

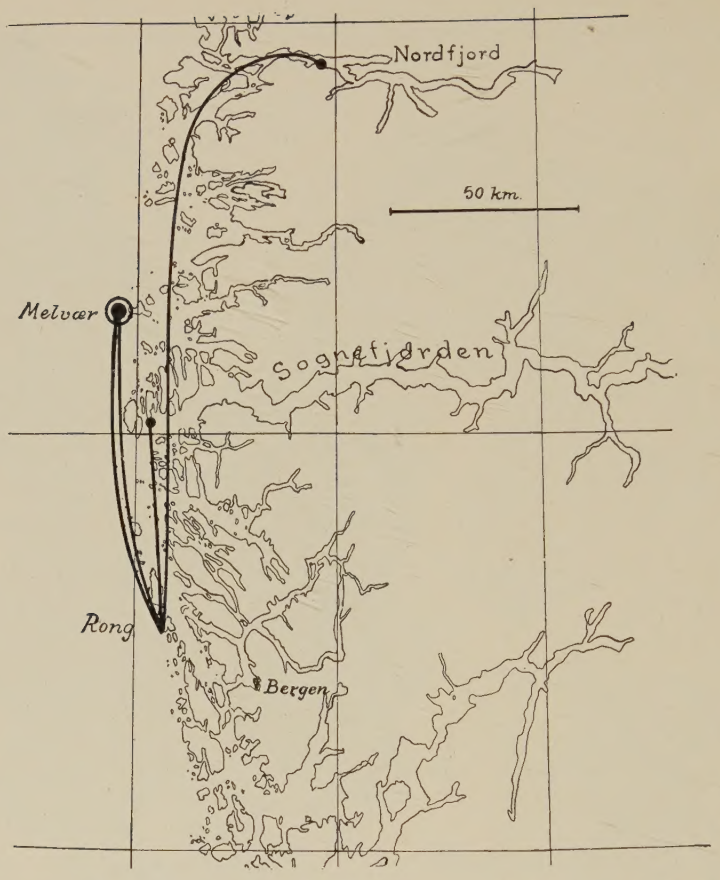


Fig. 6. Migrations of two Salmon marked at Melvær, recaptured at Rong and again liberated. (From Dahl and Sømme, 1937).

For instance, referring to the chart for the Rong marking in 1935, Fig. 2, we see that a small number of fish (37) marked on the open coast gave recaptures over an enormous area, ranging from Trondheim to the south of Sweden and even to Scotland. The coastal fish are mainly seeking their way to distant grounds, while the fish which have entered the inner waters seem to be making the final approach to their goal.

In 1936 Mr. W. J. M. Menzies, Inspector of Salmon Fisheries for Scotland, communicated to us his intention to resume the marking of clean salmon in Scotland. He also told us that he should like to test the type of addressed mark that we had introduced in 1935, and in his 1936 marking operations on the north-west coast of Scotland he employed a certain number of our type of mark. As a result of this we had that year the pleasure of being able to forward to Mr. Menzies a grilse taken at the mouth of the Sognefiord. This fish had been marked a little south of Cape Wrath on the north-west coast of Scotland, on 8th June 1936, and was retaken on 29th July in the same year, and was the first salmon proved to have crossed the North Sea in the direction from Scotland to Norway.

A very interesting point about this fish was, as Menzies pointed out[2]), that its scales showed that it had not spent its parr life in any Scottish or English river. The parr part of the scale indicates a type of growth very like that observable in western Norway.

In 1937 we abondoned the Rong station, continued our operations at the old stations of Melvær and Titran, and eventually started a new station in arctic Norway at Breivik, on the island of Sørøy in west Finnmark. The small station at Stavøy was also continued. The following numbers of salmon and grilse were marked at these stations in 1937:—

Melvær	Titran	Breivik	Stavøy	Total
219	130	464	11	824 fish

[2]) W. J. M. Menzies: The Movements of Salmon marked in the Sea. The North West Coast of Scotland in 1936. Fisheries, Scotland, Salmon Fisheries 1937 No. 1.

Fig. 7. Migrations of Salmon marked at Stavøy, Agdenes 1936. (From Dahl and Sømme, 1937).

Of the total of 360 fish marked at the southern stations 143 fish were recaptured, yielding a percentage recapture of 39·7 %, against 47·3 % and 47·7 % for 1935 and 1936.

Of the 464 fish marked at the new station in Arctic Norway (Breivik) 137 recaptures were recorded, giving a percentage recapture of 29·5 %. The probable reason for this comparatively low percentage recapture may be either that sea fishing in Finnmark is less developed, or that there was some difference in the method of marking adopted at Sørøy, as will be described later. The distribution of the recaptures from the marking stations at Melvær and Titran on the whole resembled that of the previous years. The Melvær fish were, as in 1936, mainly recaptured in the Hordaland—Sogn districts, especially in the Sognefiord with its branches and rivers. 7 fish were retaken as far south as between Karmøy and Lista (against 6 in 1936), 2 fish were retaken in eastern Norway (against 2 in 1936), and 3 fish were taken in Sweden (3 in 1936). Northwards along the coast the recaptures were fewer than in 1936 but a couple of fish were retaken farther north, at 65°56′ N. Lat. (against 64°30′ N. Lat. in 1936). In 1937 the recaptures from Scotland amounted to 3. There was also 1 recapture from the English side of the River Tweed and finally one doubtful recovery from Sidmouth in the south of England.

The Titran results in the main corroborate the results from previous years. The majority of recaptures occur in the Trøndelag districts. Towards the south the recaptures decrease through Romsdal to Sogn and Fjordane, from which latter only one recapture was recorded. North of the Trøndelag we find 2 recaptures in Nordland and 1 in Troms. Excepting the long migrations to Oslo Fiord and the White Sea in 1935 and the migration to Scotland in 1936 the results from the Titran station have been very much alike in all years.

The Stavøy station at the mouth of Trondheim Fiord gave practically the same results as

Fig. 8. Chart of the whole Area of Migration of Salmon recaptured 1937, showing Migrations of 400 km. or more. A number of long migrations have been omitted. (From Dahl and Sømme, 1938).

were obtained in 1936; the majority of the fish were retaken in the inner parts of Trondheim Fiord and its rivers. As a curiosity, I may mention that on the day I arrived at this station to begin my marking work, a fish marked by me 5 days previously at Titran had been retaken in the net I was about to use. On the following day I marked 4 fish and 1 of these was retaken in the inner parts of the Trondheim Fiord 2 days after, which is about the same time it took me to reach Trondheim by steamer.

The migrations from the Breivik station in arctic Norway yielded very striking and peculiar results. Only two recaptures were made in more southern districts, these having migrated 215 and 240 km. in a south-westerly direction to the coast of Troms Fylke.

The main trend of the migrations was eastward, the great majority of recaptures being recorded from the western and eastern coasts of Finnmark with its fiords, and mainly from its long rivers, the great Tana River accounting for most of them. In addition, 5 recaptures were recorded from the short Finnish coast adjoining the Barents Sea, the Petsamo and the Fisher Peninsula, and from the Murman coast, the Tersky coast and the White Sea, mainly from estuaries and rivers. 26 recaptures were recorded and reported to us by various Soviet authorities. One recapture was recorded even from the River Petchora, which is considered as the eastern limit of *salmo salar*, the fish having travelled 1870 km. in 55 days (the maximum speed in the year in question was 99 km. a day — 1085 km. in 11 days). The distribution of the recaptures from the Breivik station may be seen from the following table:—

Number of Recaptures.

Station	Troms	Finnmark[1])	Finland	Soviet Russia	Total
Breivik	10	95	5	27	137

A very interesting illustration of the extent of the migrations of salmon from the coasts of Norway in 1937 will be found in the chart in Fig. 8, which shows the long migrations of salmon from our various stations. It must be noted, however, that a number of long migrations from Breivik to Finnmark have been omitted, to avoid overcrowding the chart with lines.

[1]) Including the Finnish shore of the Tana.

As will clearly be seen from this chart, 1937 salmon marked on the coast of Norway xtended their migrations to the greater part of the oastal area of Europe inhabited by the salmon.

Another interesting instance corroborating the xistence of the homing instinct is connected with ur Scottish recaptures this year. In some instances ese recaptures were recorded from rivers. From e Rivers Tweed and Forth the returns were ccompanied by scale samples from the fish. Ir. W. J. M. Menzies who has had great xperience of salmon scales from Scottish rivers, as kindly examined these scale samples and states a letter to me that the parr growth of the scales question in every way conformed to the parr rowth of the rivers in which the fish were recaptured.

As regards the distribution of the recaptured sh in sea and river recaptures we have tabulated e proportion found each year. The few fish whose cality of recapture was unknown have been mitted. The figures obtained are given in the llowing table:—

ercentage Recaptures in Estuaries and Rivers.

All Stations 1935	18·6 %
„ „ 1936	14·1 %
Southern stations 1937	14·8 %
Breivik station 1937	49·2 %

We see from this that the stations on the west ast of Norway and in the Trondheim district ow a low percentage of fish recaptured in rivers d river mouths, which is very similar to the low rcentage found in our statistics relating to the antities of salmon taken in the rivers as compared th those taken in the sea. The results from the røy markings show, however, an almost equal tribution between sea and river, in good accor- nce with the fact that sea fishing in Finnmark is less developed than in more southern parts of rway. Indeed, in northern Russia the main hery seems to be in estuaries and rivers. Nearly the Russian recaptures for which the locality recapture was recorded were made in rivers or er mouths.

In reviewing our results from the various tions we have almost invariably found that fish rked early in the fishing season are more liable recapture than fish marked towards the end of season. In other words, the chances of the fish aping capture increase with the advancing season. have recorded in our papers what we have nd in the various years, and will here state only at we found in 1937.

ercentage Recapture by Periods of the Season when marked. 1937.

	Titran	Melvær	Breivik
V—21. VI ..	45·4 %	51·3 %	29·6 %
VI—5. VII .	37·2 %	33·9 %	29·4 %
VII—7. VIII .	10·3 %	33·8 %	28·3 %

At the southern stations, Titran and Melvær, we notice a considerable decrease in the relative occurrence of the recaptures. This is due to the fact that the commercial fishery, which in the southern and middle parts of the Norwegian coast is mainly a sea fishery, practically ceases by the middle of July. In Finnmark, however, we find no such effects of the advancing season. The percentage recapture is almost the same at whatever part of the season the fish were marked. This is no doubt due to the preponderance of river netting and a fishing season which lasts till autumn, features which are common to both Finnmark and northern Russia.

We may remark briefly upon our methods of marking the fish. We must first emphasize the fact that success is largely dependent on the condition in which the fish leave the marker. In our first experiments, during the marking process we held the fish either on the bottom of the boat, in a fold of the net, or in a man's lap or between his knees. We soon found out, however, that to keep the fish quiet, it was necessary to let the fish lie on their belly. We soon constructed a kind of narrow cradle of smooth zinc plate, in the bottom of which a centimetre gauge was stamped. In this cradle the fish lie very quiet and the length can be easily read off. Various devices have also been adopted, such as using the eyed and grooved needles from the large cobbler's sewing machines for pushing the silver wire through the frontal cartilage of the dorsal fin. By such contrivances the time taken in marking the fish is reduced to a minimum and I should think that most fish are marked in less than half a minute.

Moreover the condition of the fish that we have used for marking purposes has always been most carefully watched and it has been a rule rigorously kept that all fish showing signs of being the worse for the handling in the nets should be rejected. We have thus only used fish which we deemed certain to live. But even after this severe sorting we have graded the fish according to condition: Prime (Max.), Middle (Med.), and Weakest (Min.). Tabulating the recaptures for each of these 3 grades, of which, however, the two lower grades contained comparatively few fish, we find no marked difference in the recaptures for the various grades of condition, a fact which to us justifies the belief that our rejection of the unfit fish has been severe enough. In 1937, at the Breivik station Sømme tried the experiment of not subjecting the fish to such severe criticism as usual, rejecting only the definitely moribund fish, so that net-marked fish which were not absolutely sure to die were employed for marking. All the fish were graded (Max. Med. and Min.), as at our other stations.

A comparison between the Melvær, where all doubtful fish were ruthlessly rejected, and the Breivik (Sørøy) results gives the following figures.

Condition	Melvær Recaptures	Breivik, Sørøy Recaptures
Max.	41·7 %	33·4 %
Med.	39·4 %	19·8 %
Min.	40·0 %	7·1 %

It may be seen, then, that what we considered inferior fish at Melvær were retaken at just the same rate as the prime fish, but this was not so at Breivik. The fish classed as inferior there were really not so suitable as the best, and the dwindling percentages prove that they should have been rejected.

At Breivik S ø m m e also kept a record of net-marked fish. For fish in the best condition (Max.) the experiment gave the following results:—

Condition	Number of fish Breivik		
Max.	Marked	Recaptured	
Not netmarked	283	101	35·7 %
Net-marked	67	16	23·9 %

The percentage recapture is thus about 10 % lower in case of the net-marked, but otherwise well-conditioned fish. These experiments show on the one hand that the comparatively low percentage recapture from the Breivik markings must to a certain extent be due to the lower standard of sorting the fish employed for marking, and on the other hand they clearly demonstrate the necessity of the rigorous rejection of unsuitable fish which we have practised at our other stations.

One of the problems regarding the method of marking in which we have been greatly interested is to make the mark as visible as possible and so to attract the attention of the fisherman himself. In this way we should obtain first-hand information about the fish and the exact place of capture. When the addressed silver marks, described in our 1936 paper, were employed, it happened in a ccertain number of cases that the mark has escaped the fisherman's notice and has been received only after having passed through the hands of the fisherman to the fish buyer, the exporter or the retail merchant. In such cases we miss valuable information which can only be obtained at first hand. It also happens sometimes that fishermen who catch marked salmon forward the mark without detailed information as to the capture and the fish.

At the time when the results were coming in from our experiments with addressed marks in 1935 and 1936, Mr. E i n a r L e a, the well-known biologist, conceived the idea of developing still more suitable types of marks not only for salmon but also for other fish. Mr. L e a's idea was to employ celluloid instead of silver, thereby gaining the advantage of a lighter mark, which by reason of their size and bright colouring would be more easily observed by the fisherman. These marks will be described by Mr. L e a in a paper in the publications of the Academy of Science, Oslo.

In the summer of 1937 we accordingly made some experimental markings with two types of Mr. L e a's marks, both made from celluloid.

One of the marks, called *the A. mark*, is a cylinder of a total length of 30 mm. and a diameter of 5·5 mm. In one end is a little plate with a perforated ridge where the silver wire is fastened. The colour is bright yellow with violet ends. The cylinder is stamped on the outside with a number and the following text:—

Zool. Museum, Oslo, A No.....
Skjær av endene
brev inni.
Cut ends
letter inside.

Inside the cylinder a paper band 215 mm. long and 19 mm. broad is rolled up. It is stamped with a serial number and contains a printed request addressed to the fisherman.

The other one is a flat, oval celluloid mark described as *the B. mark*, length 31 mm., breadth 13 mm. On one side the following legend is printed on a yellow label:—

B. *(no.)* Send til
Zool. Museum Oslo
Præmie 5 Kr.

On the other side, also on a yellow label, is printed:—

Opgi sted, tid, redskab, lengde,
vegt, vedlegg skjæl (risp).

The edges of the mark are painted a bluish violet colour.

In order to see whether these marks are now returned to a greater extent than the original silver marks or lead to better information about the recapture, we have periodically employed these new marks alternately with silver marks. Over a definite period we therefore marked every other fish with silver marks and with either A. or B. marks.

The results are shown in the following table:—

(See following column).

In regard to the *A. mark*, which has been tried as an alternative at Melvær and Breivik, it will be seen that at Melvær this mark gave a better percentage recapture than the silver mark (46·7 % for the A. mark and 35·9 % for silver). But at Breivik, where a similar number of alternate markings were made, the silver mark was slightly superior (33 % for silver and 30 % for A.). The B. mark was tried at Titran, Stavøy, and Breivik

Comparison of Recaptures for Marks of different Types used alternately.

I. Titran

Date	Number marked	Type of mark	Number recaptured	% recaptures	Remark
V/23—V/24	6	silver	5	83·3	
V/30—VII/5	40	B.	23	57·5	marked alternately
	40	silver	9	22·5	marked alternately
VII/5—VII/30	44	silver	9	20·4	
Total	130	both	46	35·4	
Of these	90	silver	23	25·6	

II. Melvær

Date	Number marked	Type of mark	Number recaptured	% recaptures	Remark
V/10—VII/16	107	A.	50	46·7	marked alternately
	106	silver	38	35·9	marked alternately
VII/17—VII/19	6	silver	1	16·7	
Total	219	both	89[1])	40·7	
Of these	112	silver	39	34·8	

III. Breivik

Date	Number marked	Type of mark	Number recaptured	% recaptures	Remark
V/29—VI/20	100	A.	30	30·0	marked alternately
	100	silver	33	33·0	marked alternately
VI/20—VI/27	105	silver	30	28·6	
VI/28—VII/5	30	B.	9	30·0	marked alternately
	30	silver	6	20·0	marked alternately
VII/10—VII/25	99	silver	28	28·3	
Total	464	all	136[2])	29·3	
Of these	334	silver	97	29·1	

IV. Stavøy

Date	Number marked	Type of mark	Number recaptured	% recaptures	Remark
VI/13—VI/27	5	B.	4	80·0	marked alternately
	6	silver	3	50·0	marked alternately
Total	11	both	7	63·6	

[1]) Total number of recaptures 90 (41·1 %); of these 1 was of unknown type.

[2]) Total number of recaptures 137 (29·5 %); of these 1 was of unknown type.

has everywhere appeared superior to the silver k». How far this superiority goes is very diffi- to decide. If we scrutinize the figures closely, can easily see that we should be careful how trust them. For instance, it is significant that Titran the highest percentage recapture falls to silver marks employed alone. At Breivik silver employed alone gives only a slightly smaller percentage recapture than the B. mark alternating with silver. At Stavøy the figures are so small that the recapture of only one or two more fish with silver marks would nullify the superiority of the B. mark. More certain conclusions can only be attained by continuing the experiments.

2

SOME PRELIMINARY OBSERVATIONS ON THE MIGRATIONS OF SALMON *(SALMO SALAR)* ON THE COASTS OF SCOTLAND.

BY

W. J. M. MENZIES, F. R. S. E.

Inspector of Salmon Fisheries of Scotland.

FIXED nets for the capture of salmon were first used on the coast of Scotland just over one hundred and ten years ago (ca. 1827) and from the success which they immediately obtained, and which has been continued, it is evident that the salmon in the course of their sea life come close inshore. At first no doubt it was not realised whether the fish were feeding or were on migration when captured. In later years it has become clear that the fish have ceased feeding before they reach the coast and that they may be considered to be then on their way from the feeding to the spawning grounds. For long it was thought that the fixed nets were only of importance to the rivers near which they were situated and that the fish taken by them were to be regarded as part of the stock of the neigbourhood. It was clear, however, that in certain cases this opinion had to be interpreted somewhat widely for nets set at considerable distances from the mouths of rivers of any importance were often quite successful.

Little can be learned of the precise movements of salmon from commercial fishing beyond the fact that, on a comparatively unindented coast, such as the east or north coasts of Scotland, salmon are to be found at relatively considerable distances (twenty or more miles) from the mouths of rivers of importance. It has been assumed that the fish swim along the coast close to the shore for considerable distances and it has been stated that, at various parts of the coast, the line of migration is predominantly in one direction. On an open coast where bag nets are set singly and at some distance (quarter to half a mile) from each other it is not impossible that the fish should swim more or less parallel to, and within a few hundred yards of, the shore. But further examination in more intensively netted areas shows that this suggested movement cannot occur. In some districts, e.g., St. Cyrus Bay, Lunan Bay (both near Montrose), and Largo Bay in the Firth of Forth bag nets have been fished for very many years the one beyond the other until sometimes six or eight are in a straight line stretching for roughly half a mile from low water mark. This practice of "out-rigging" the nets is extending and this year it was successfully employed at the experimental marking station on the west coast where only single nets are still usually employed.

When lines of nets are fished in this fashion and two lines of six or more nets each are fished with equal success within two hundred yards or so of each other, it is clear that the migration of the salmon along the coast cannot be a simple progress in one direction and in a comparatively straight line. The Figures 1 and 2 are charts of St. Cyrus and Lunan Bays showing the spacing of the nets and the number used at each position. These illustrate how impossible it would be for salmon to enter the bays only from either end and to attempt to swim along the shore or for them to do so from any particular point within each bay. For all the nets shown in these figures to be successful it is clearly necessary for the salmon to approach the bays from any direction and towards any part of the bay. Similarly were salmon to follow this alleged habit then those released from a marking station would all be captured by a particular set of nets in either one direction or the other and were any considerable journey started in the direction of a thickly netted area the attempt would soon be terminated by the capture of the fish.

Consideration of all the facts shows that when making a definite migration the salmon may do the journey in a more or less direct course but at some distance, probably greater than half a mile, from the coast. On the other hand when near its destination, or when waiting for water to tempt it to ascend a river, it moves in a straight line along the shore for only a very short distance and these little journeys close to the edge of the water are interspersed between quite definite on and off shore movements that may extend to a distance of probably several miles from high water mark.

As justification for the assumption of a movement predominantly in one direction or the other along the coast, fishermen state that they see the fish

St. Cyrus
Roadside
Whitehill
Lochside
Kennels
Lodge
Cistern
Scotston
Old Dam
Kirkside
Dovecot
Kirkside Cottage
Kirkside Fishing Station
Whitecraig Quarry (Disused)
Warburton
Nether Warburton
Pathhead
Human Remains found
Sick Man's Shade
Waterside
Fisherhills
RIVER NORTH ESK
H.W.M.O.S.T.
Saltings
Mud
Salt Ings
Coc'k Ham Bents
SANDS OF ST.
Hydraulic Ram
Police Station
Mercurylone
Mercury Lane
Mercuryburn
Manse
Collis' Row
Long Row
Hotel
Goods Shed
Church
Burnside
Wellgrove
L.N.E.R. BERVIE BRANCH
Church (Site of)
Dam
Stone
Lower

Dam
Nether Woodston
Stons
Woodston Fishery
Stone
Church
Remains of Church
Stones
High Water Mark of Ordinary Spring Tides
CYRUS
Haim of Mathers
Rock Hall
Tangleha'
L.W.M.O.S.T.
Milton Ness
1 Mile

Fig. 1

C R A I G
L U N A N
L U N A N B A Y
Boddin Point
Lunan
Lunan Bay Station
ARBROATH & MONTROSE SECTION
1 Mile

Fig. 2

0
50
100 Miles
ORKNEY ISLANDS
CAPE WRATH
BUTT OF LEWIS
BARVAS
LEWIS
GRIMERSTA
BARVAS
L. HOPE
HELMSDALE
HOPE
BARVAS
BRORA
HELMSDALE
BARVAS
CARRON (N. ROSS)
NAVER
GRIMERSTA
DUNCANSBY HEAD
R. NAVER
R. HALLADALE
R. THURSO
WICK
HELMSDALE
R. HELMSDALE
HELMSDALE
BRORA
LOCH SHIN
R. BRORA
HELMSDALE
MORAY FIRTH
BARVAS
AWE
HELMSDALE
NAVER
NESS
HELMSDALE
SPEY
DEVERON
HELMSDALE
HELMSDALE
R. CONON
AWE
SKYE
R. BEAULY
INVERNESS
R. FINDHORN
R. SPEY
R. DEVERON
DEVERON
HELMSDALE
SPEY
DEVERON

L. Ness
ABERDEEN
DEVERON
HELMSDALE
R DEE
DEVERON
DEVERON
MONTROSE
R. STH. ESK
R. TAY
FIRTH
OF
TAY
PERTH
MULL
R.
AWE
R. FORTH
STIRLING
SPEY
TAY
FIRTH OF FORTH
EDINBURGH
R TWEED

Fig. 3

o moving (by watching the progress of a shoal in hich the fish are jumping) or that the fish are elieved to enter the nets from one side more than rom the other (a bag net has a wall of netting at ight angles to the shore which leads the fish into trap and is normally arranged so that fish may nter the trap from either side although very rarely is made so that fish can enter from only one ide).

Salmon certainly do have two quite definite but emporary movements. The first is that they come o the lee shore in a most marked manner; with wind blowing on to the shore bag nets will fish ell but with a wind blowing off the shore the atches are invariably poor after the first day of he change of wind. If then the prevailing wind in Scotland normally south-westerly) blow along ny particular piece of coast salmon close inshore ill normally travel with the wind and can be seen o jumping and moving. Salmon when close to he shore also travel temporarily with the tidal tream even if that stream be an eddy and not the rue tidal stream. In certain situations, close to a romontory or in a bay, the true tidal stream may e succeeded by an eddy stream flowing in the ame direction; here salmon will move mainly n the one direction, which is that of the longest lowing stream, combined of true tide and eddy. ishermen working in such situations will say that he fish run in a certain direction. But it is a urely local effect and has no relation to the ain run of fish along a larger section of the coast. he alleged general movement of salmon in a ertain direction along certain parts of the coast as on several occasions been proved by our arking work to be incorrect.

The marking of salmon as means of providing nformation regarding the life history of the fish as started in Scotland in 1896 and between then nd 1912 some few indications were obtained of he possible movement of salmon along the coasts t considerable distances from their river of origin. he marking was confined to kelts and some of the onger journeys indicated by these marked fish and ther kelts marked subsequent to 1912 may be uoted.

On the map in Figure 3 I have indicated the osition of recaptured fish by placing at the ecapture station the name of the river in which hey were marked. It is necessary to remember hat they were marked as kelts and were retaken hen clean. When finally caught they may be egarded as on their way back to their original ivers. The names of certain rivers will be found o predominate but no significance is to be ttached to this: it simply indicates the districts here most marking was done. If we take first he river represented most numerously — the Helmsdale — we find fish retaken all the way rom the north coast down to Aberdeen. No ignificance need be attached to the recaptures in the inner Moray Firth between the Deveron and Wick, since these fish are within close range of their own river. It is hard to attach the correct significance to the other fish which appeared in diametrically opposed directions. The two taken on the north coast, where another fish from the Brora which adjoins the Helmsdale was also caught, suggest a migration in from the north while the two, caught respectively near Peterhead and Aberdeen, to the south equally indicate a move in from the south. As I shall explain later it is possible that these apparently divergent results are the true indication of divided routes of migration.

In distinction from the Helmsdale results we have a rather striking uniformity of recaptures to the south of the place of marking in the case of salmon marked in Spey and Deveron. These fish have been caught between Peterhead and Aberdeen but not at all on the north coast. A similar move is also shown by a single fish from the Naver on the north coast which was recaught near Tarbat Ness in the inner Moray Firth. On the north coast two fish from the west side of Lewis (Grimersta and Barvas respectively) were retaken in or near Thurso Bay and another from the West Ross Carron at Melvich. On the West coast there are only two recaptures of note but when compared with the results of marking in the sea they are of particular interest. Two salmon marked in the Awe which enters the sea near Oban were captured on the shores of the Minch and were thus returning to their river from a northerly direction.

It became clear that kelt marking was not going to give any very direct answer when carried out on the scale that was then possible and a more direct attack on the problem of the migrations of the salmon along the coast of Scotland was planned. In the normal commercial method of capture in the sea by means of fixed traps (bag nets or fly nets) into which the fish swim and in which they remain swimming without being caught in the meshes of the net, salmon are retained without any harm until they are removed for the market. Such engines are, therefore, ideal for experimental purposes although, owing to the fact that almost all the most profitable sites are occupied with commercial fisheries, it is difficult to put the nets for experimental purposes in places where an adequate number of fish can be caught.

Experimental netting took place from 1913—1915, 1920—1921 and 1936—1937 all inclusive and the exact sites of the various stations are shown on Figure 4.

In 1913 a start was made in catching clean salmon in bag nets, marking them and releasing them again into the sea. The site chosen was at the head of the Moray Firth (see Figure 4) where salmon were known to be reasonably plentiful and in the neighbourhood of which are large numbers of bag nets. This site was of interest because it was quite close to the bottle neck of the

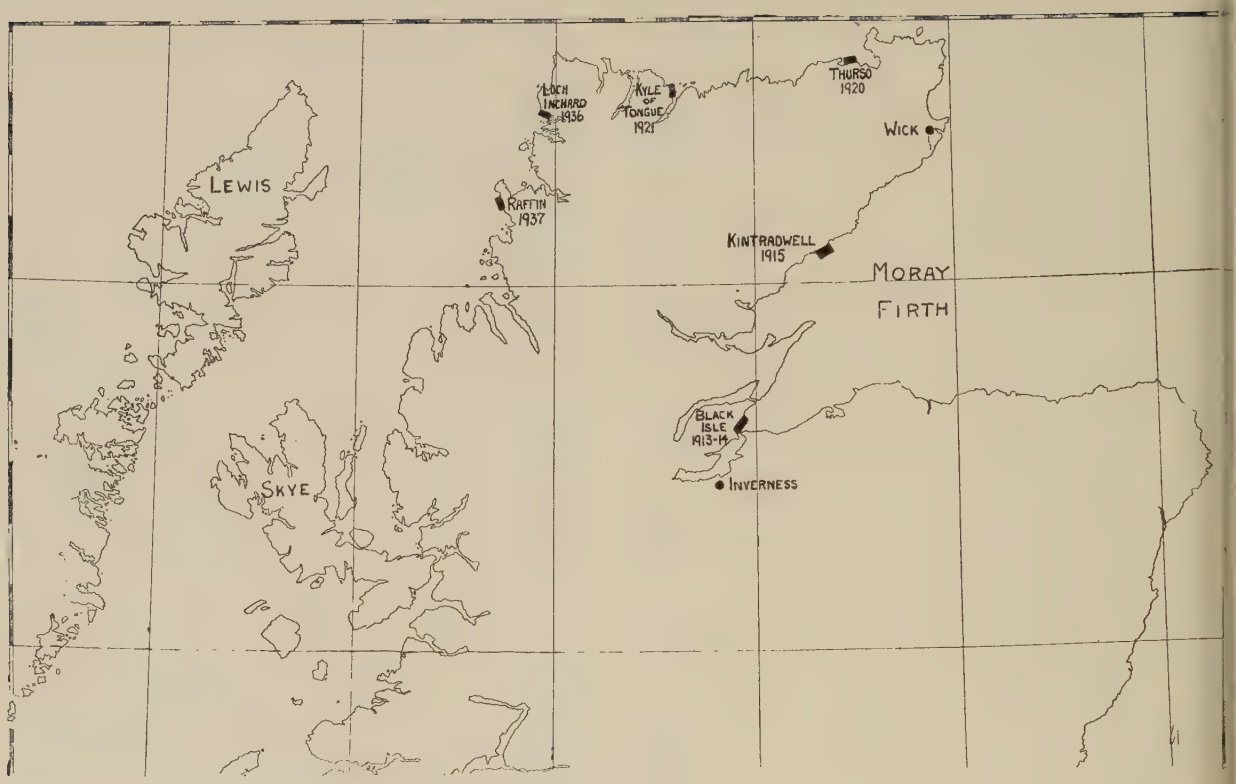


Fig. 4

narrows leading to the Inverness Firth: inside the narrows fixed nets are not set. These nets, therefore, were the last fixed nets which the fish would encounter on their way up to the Ness and Beauly rivers, the mouths of which are situated near the top of the firth. The experiment was continued during the summer of 1913, for the greater part of that winter and in the summer of 1914, 1019 fish were marked and 28 per cent. of these were recaptured. The results fall quite clearly into two divisions, being those which were obtained in the summer months of May to August inclusive and those for the winter months October to January, also inclusive.

In such a situation one would expect a goodly proportion of the fish to be on their way to the Ness and Beauly rivers. To a limited extent this proved to be the case (see Figure 5). But in addition to these there were others, and they were far more numerous, which, after approaching the bottle neck, again turned out to sea, and were retaken either in some of the numerous nets along the shores of the Moray Firth or in the rivers which flow into it. A number were found in the sweep nets of the Kyle of Sutherland at Bonar Bridge, and others in Spey, Findhorn, Nairn and Conon (whither a considerable number travelled). One was taken in the Fleet the mouth of which is close to the Kyle of Sutherland.

The recapture in the sea nets should perhaps be of greater interest, but they are a little uninformative, since, viewed as a whole, they merely represent the fish as scattering along the shores of the Firth between Rosemarkie and Tarbet Ness to the north, and between Fort George and Port Gordon on the east. It is easier to visualise the fish in this rather restricted area as travelling on a roughly circular course round the narrow part of the firth, while waiting for water to reach their own river, than to imagine them making a definite course and journey for which either one shore or the other might form the guiding line. I do not consider that, under the circumstances, the exact number of fish caught on each side of the firth forms any sort of reliable index of the movement but in the twenty-two miles from Rosemarkie to Tarbet Ness seventy four fish were taken, and in the same distance on the southern shore (from Fort George to the neighbourhood of Burghead) exactly the same number were caught. Outside this radius of twenty-two miles we find only sixteen fish taken in coastal nets, and of these, twelve were grouped on one or other side of Spey mouth. Forty-five fish were also taken in estuarial or fresh waters

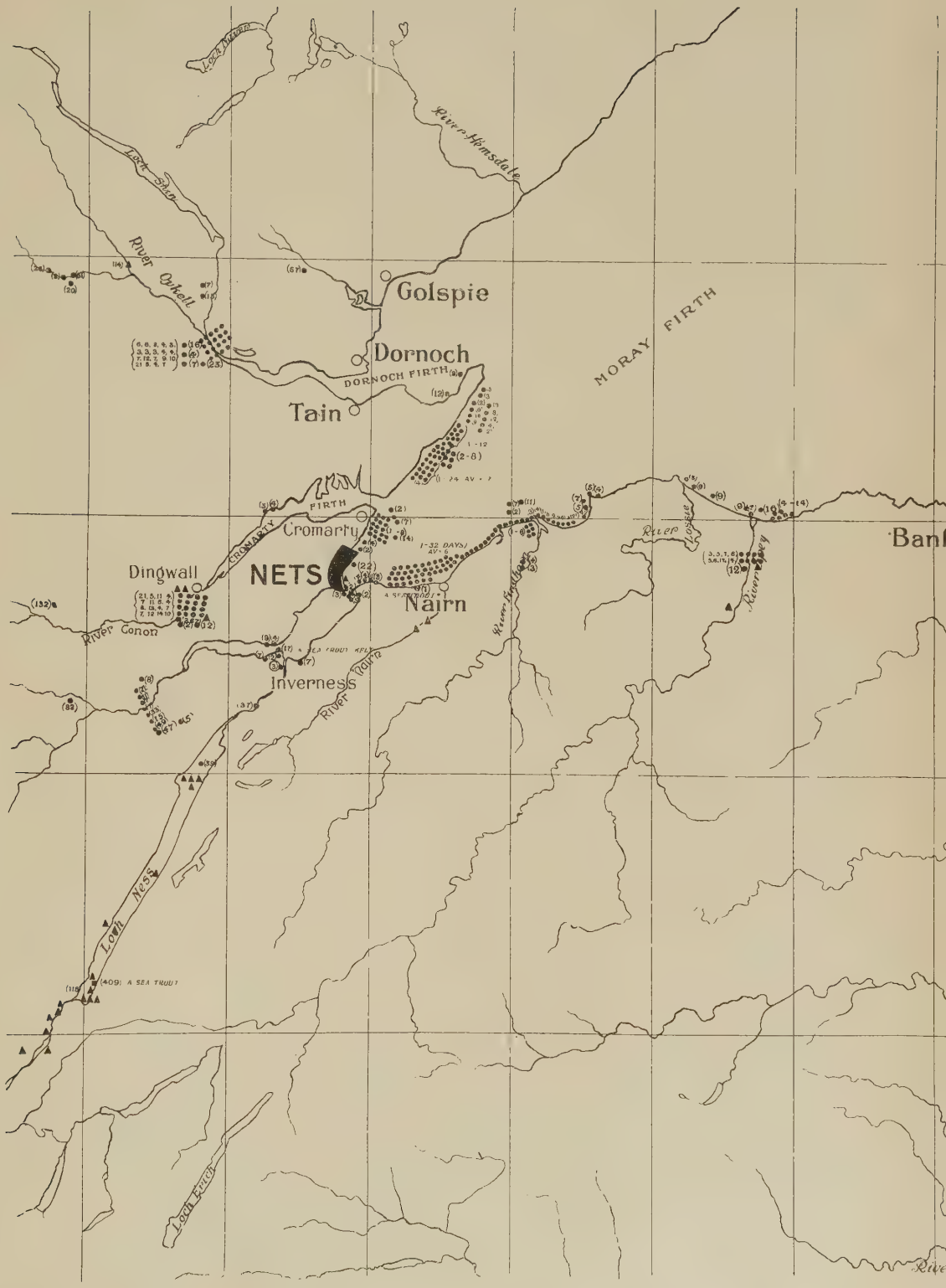
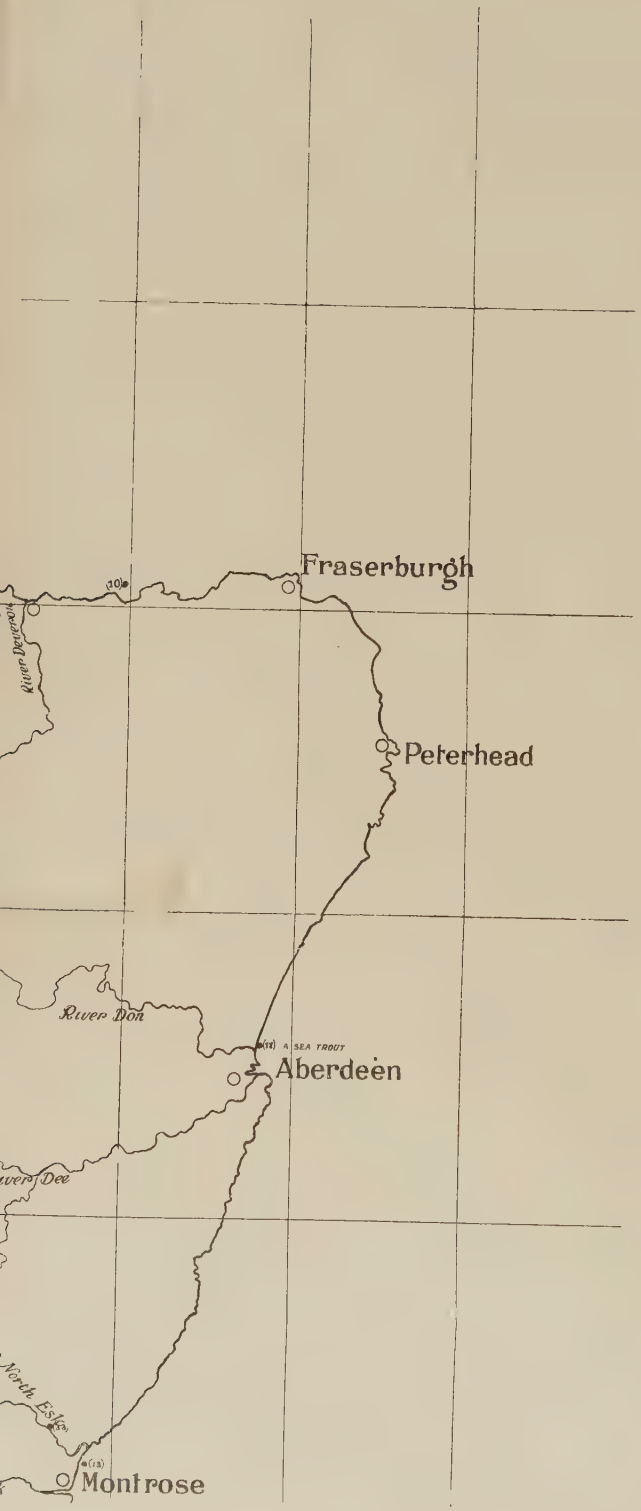

Golspie
Dornoch
DORNOCH FIRTH
Tain
MORAY FIRTH
Cromarty
FIRTH
CROMARTY
NETS
Dingwall
Nairn
Inverness
River Conon
River Nairn
River Findhorn
River Lossie
River Spey
Loch Ness
Loch Fleet
River Oykell
Loch Shin
River Helmsdale
(409) A SEA TROUT

Fig. 5


Fraserburgh
(10)
River Deveron
Peterhead
River Don
(11) A SEA TROUT
Aberdeen
North Esk
(15)
Montrose

DUNNET
FRESWICK BAY
KEISS
R Thurso
CAITHNESS
WICK
LYBSTER
LATHERON
DUNBEATH
BERRIEDALE
SUTHERLAND
R Helmsdale
HELMSDALE
KINTRADWELL
R Brora
NETS
BRORA
R Cassley
R Oykell
R Shin
Kyles of Sutherland
MORAY FIRTH
BONAR BRIDGE
DORNOCH FIRTH
TARBAT NESS
PORTMAHOMACK

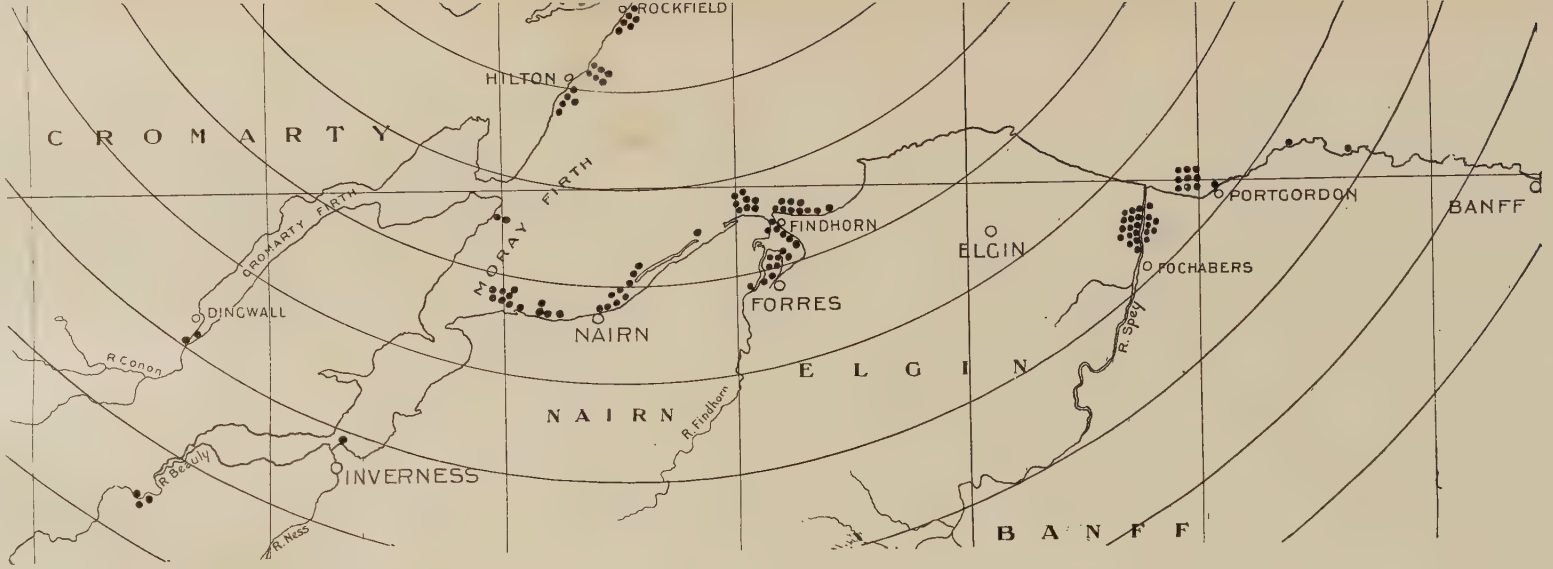

ROCKFIELD
HILTON
CROMARTY
CROMARTY FIRTH
MORAY FIRTH
FINDHORN
ELGIN
PORTGORDON
BANFF
FORRES
NAIRN
DINGWALL
R. Conon
R. Beauly
INVERNESS
R. Ness
R. Findhorn
R. Spey
NAIRN
ELGIN
BANFF

Fig. 6

eyond the twenty-two miles limit, and of these hirty were in the Kyle of Sutherland, and eleven the Spey, districts.

Apart from these localised movements we have ecords of five other fish which travelled beyond — in four cases far beyond — the local limits. ne was taken at Gardenstown on the east of Banff, nd some seventy miles away from our nets; the our others (all grilse) being the balance of the rty-five fish referred to above, continued on und Buchan Ness, two for 160 miles to the North sk, while the two others ascended the Firth of orth, and were taken near Alloa, 250 miles from e place of marking.

Viewing the experiment as a whole, probably the ost noticeable point which emerges is the number fish — thirty — which have moved north to the yle of Sutherland and to the rivers which flow to it. This is a greater number than were taken any other estuary and river, although the place marking was situated in the outer estuarial aters, as it were, of the Ness and Beauly, and not r from the direct line of approach to the Conon. the Conon twenty-three marked salmon were und, eleven were taken in the Beauly, and enty-two in the Ness. The majority of the Ness sh were winter fish, which were marked between ctober and January.

The conclusion we can draw is that while a rtain number of the summer fish were going rth on their way to the Kyle of Sutherland, the eat majority confined their movements to an area the firth within twenty-five miles of Rosemarkie, d were either directly on their way to the rivers tuated to the west and north of Spey and to the uth and east of Conon at the head of the Cromarty rth, or were merely waiting for a favourable portunity to ascend them. We have no evidence, her than the movement to the Kyle of Sutherland, any definite lines of migration, nor were any sh, marked when grilse, recaptured as maiden ring or summer fish in the following year.

The winter fish displayed quite other characristics and since commercial nets were not then use (the close season extends from approximate- the end of August to the middle of February) ne of them were expected to be caught in the a. The possible rivers of capture were also mited since comparatively few Scottish rivers ld clean winter fish. As events subsequently roved, most of the marked fish continued up what pears to be the natural channel to the Ness with much smaller proportion to the Spey.

The results of these marking experiments of 913—1914 show that the fish found at the inner rrows of the Moray Firth are not in the majority cases proceeding to one of the rivers at the head the firth, but may be natives of any of the oray Firth rivers and, while waiting to ascend to fresh water, have a comparatively limited uising range within the inner part of the firth. From these inner waters few fish make long journeys and those that do so travel south.

The next marking station, in 1915, was about 35 miles to the north of the first and towards Duncansby Head. (1773 fish marked, 23 per cent. recaptured). This station may also be regarded as well within the waters of the Moray Firth and the migrations of the majority of the fish were found to be similar to those at the first station. The notable change was that the area of movement was enlarged and instead of extending from Tarbat Ness across the firth to Burghead, it was enclosed by a line drawn from Lybster (South of Wick) to the mouth of the Spey.

A much larger number were taken in the Kintradwell than in the Black Isle nets, and on viewing the map, Figure 6, we see a correspondingly larger number of recaptures set out, the majority of them being again grouped on the coast within thirty miles of the place of marking. Before we can rightly consider the true significance of these migratory movements, we must remember that the summer of 1915 was very dry in the north-east of Scotland, and that there was no spate from the time the grilse, which formed the majority of marked fish, began to run until the end of July; further, that practically the whole of the recaptures were made prior to, or immediately at, the commencement of the spate. When the flood came, the salmon, both adolescent and adult, deserted the sea for the river.

Between the Black Isle and the Sutherland coasts there is also a great difference. Along the Ross-shire shore and the southern side of the Moray Firth practically every available position is occupied by a fly net or by a bag net, and very often four or five of the latter are outrigged, the one beyond the other, into the sea. Along the Sutherland coast there are neither fly nor bag nets from the entrance to the Dornoch Firth to the county march at the Ord of Caithness. Debouching from that coast line are two rivers of major and one of minor, importance from a salmon fishery point of view — the two former being Helmsdale and Brora and the last the Fleet. Farther north, beyond the Ord of Caithness, bag nets are in plenty, and there also are to be found the little rivers of Berriedale and Dunbeath and the Wick river, although in the latter salmon are almost extinct.

If we again look at the map we now have a better understanding of the significance of the recaptures. The great majority were made in the first fixed nets which the fish encountered while cruising along the coast in a northerly direction, and a considerable number were also taken rather farther up the coast at Dunbeath and Lybster. Beyond Lybster the numbers caught are quite insignificant; the Wick bag-net station had only one marked fish. To the north of Wick, at Freswick there were only two, and at Keiss six. In the nets worked at the mouth of the Brora river a number

were captured, and a few farther up the river. None were found in the Fleet, but quite a number were taken on the rod in the Helmsdale. In our own nets at Kintradwell twenty-six were found for a second time and this, in conjunction with the quantities at the first fixed nets to the north seems to me significant, if we remember that the year was dry and the rivers were low. At the first glance a very marked northern migration would appear to be shown, but from the lack of recaptures in 1916 it is evident that all our fish were on the way to fresh water in 1915, and, there, must have been on their way to a river when caught and marked. If we are to take this northern migration as a fact, we shall have to imagine the destination which the fish were seeking. If it be that the fish intended to ignore the Helmsdale, it hardly seems possible that they would do so to group themselves round the mouths of the quite unimportant streams at Berriedale and Dunbeath — streams, moreover, which are patently occupied only by a comparatively small number of salmon and grilse, and not by the considerable quantity which would appear to be indicated by the recaptures in the fixed nets. Moreover thirty marked fish were caught in the Helmsdale and not a single fish in the rivers further to the north. If the important river Helmsdale is to be definitely passed, one would expect the larger part of such a considerable number of fish to proceed farther along the shore, round Duncansby Head, and to the larger rivers of the north coast. The recaptures of marked fish show that this is not the case, and the explanation would rather seem to be that we are here dealing with the bulk of the summer stock of salmon of the Brora and Helmsdale which are cruising along the coast and biding their time, as it were, until the rivers should be of a height sufficient to enable them to ascend from the sea. In this time of waiting they have a playground twenty-five miles long, clear of all nets except those of our experimental station, and here they doubtless disported themselves with freedom; but when their journeyings took them within the much-netted area of south-east Caithness many were captured, and were not released, as was the case at Kintradwell. Of an undoubted northern migration, I venture to think we can only count those nine fish which I have already enumerated at Wick, Keiss and Freshwick, and one other which proceeded through the Pentland Firth, and was caught on the east side of Dunnet Head.

The other recaptures effected in fixed nets on the coast are distinctly to the south of the place of marking, and are grouped very much in the same nets as the Black Isle marked fish were grouped, except for a somewhat distinct paucity of captures between Rosemarkie and Cromarty. We also find on this occasion rather more on the west side of Tarbet Ness, which perhaps conform to the suggestion I have made about the movements in the playground along the coast. We have to extend ou radius to a distance of thirty miles from the plac of marking to cover the great majority of th recaptures. Beyond this the only group of im portance other than those taken north of Lybste is that of thirty-five fish taken in the Spey distric about forty miles from Kintradwell.

As in 1913 and 1914, we find marked fis turning up along the Cromarty—Tarbet Ness shor in the fixed nets round Nairn an Findhorn, and few at Port Gordon, which would seem to nece sitate the extension of the previous expressed vie of the possibilities of a circular movement roun part of the Moray Firth. A wider area than wa suggested by the Black Isle results alone no seems to be involved. Salmon in the comparativel confined area may move about with some freedom and possibly may follow the whirl-pool-like set o the tide, the drift of which, after the main south going current strikes the shore and divides wes of Lossiemouth, is west, along the southern shor and then north-east past Tarbet Ness. Naturall one cannot be certain of the exact track of the fis but, since they are known to travel with the set o the tide along the shore, the circular movemen would seem more probable than the point-to-poin progress, which would be indicated by merel joining up the places of marking and recaptur with a series of straight lines.

The river recaptures from this series of mark ings are rather interesting, and show that while considerable number of the Findhorn and Spe fish have approached their destinations by th Sutherland coast, very few of those going to th Ness, Beauly, and Conon have done so. If w compare the two maps of the different markin experiments, we see clearly the change, and ho the fish coming into the bottle neck of the firt apparently do so from some direction other tha the north. The fish destined for the river inside the bottle neck — i.e., Ness and Beauly — do not extend their wanderings to the Sutherlan coast, even in a dry year, when waiting for suf ficient water to run the river, for otherwise w would have found more going to those district from Kintradwell. Another point of interest is tha of a far greater number of fish marked at Kintrad well, fewer have gone to the contiguous Kyle o Sutherland than went there from the more distan Black Isle nets.

As well as the more important recapture indicative of the general movement of the majorit of the salmon which we have considered, there ar a few fish which journey considerable distances For instance, a salmon went to Lochinver on th west coast — a sea passage 130 miles fron Kintradwell; another travelled 240 miles to th Coquet in Northumberland; and other individual to Aberdeen (112 miles), Montrose (150 miles) the Tay (200 miles) and the Coquet (240 miles).

From this marking experiment, signs of an

Fig. 7.

finite and clear line of migration are difficult find. A movement from the nets to the Helmsle a distance of some eight miles, can scarcely regarded as a definite northerly migration in ew of the distances which salmon easily travel in e sea in a short period of time; nor, for the asons I have already stated, do I regard the captures in the south-east of Caithness as indices direction. A certain number of fish have gone the rivers south of the place of marking — e.g., ndhorn and Spey. On the whole, I think it obably better to be satisfied with the provisional nclusion which we have already reached — mely, that in a dry year there is probably a cular movement of salmon round the firth in neral, with a more restricted migration of fish longing to the east Sutherland rivers along the ast of that county, and of the southern part of ithness.

In 1920 a marking station, operated in Thurso y from May to September (478 fish marked, per cent. recaptured), showed a much more stricted area of movement (Figure 7) and most recaptures were made within a very few (fifteen) miles, all being to the west of the bay although this is not completely significant since only one bag net station of small importance exists in the hard running tides to the east of the bay. The nets were set quite close to the mounth of the river Thurso and before the start of the experiment it was fairly evident that a considerable number of fish destined for the Thurso river would be caught. This proved to be the case. But the configuration of the land at Holborn Head to the west, and Dunnet Head to the east, of the bay is such as would naturally lead salmon into the bay: it seemed possible, therefore, that fish striking in to the coast in this neighbourhood might swim round the bay before proceeding further on their journey.

The rainfall was so small that there was no flood in the rivers between mid-June and mid-September and during this time no salmon entered fresh water. The marked fish consequently had ample opportunity of scattering as far as they might desire but of the 62 recaptures 38 were taken in Thurso Bay and river. Of the remainder, 17

Fig. 8.

were taken in the first nets worked in the sea to the west, and within eleven miles, of Thurso Bay and two were taken in north coast rivers only one of which — the Hope — is a significant distance (50 miles) from Thurso. Of the remaining three fish two went round Duncansby Head to Wick and the other travelled 115 miles in the opposite direction round Cape Wrath to Gruinard Bay.

Here in this Thurso Bay marking in spite of ideal conditions for the distribution of the fish we find an actual major distribution within less than half the distance covered by the Moray Firth fish. The evidence shows very clearly a local stock of salmon which have finished their main migration from their feeding grounds and are waiting for an opportunity to ascend the one of the three neighbouring rivers — Thurso, Forss and Halladale — to which they belong. While so waiting they cruise about in shoals along this very short stretch of coast frequenting temporarily first one and then another comparatively limited area according to the prevailing wind and the particular tidal stream in which they happen to be. The wider migrations are very restricted in number but, in the light of evidence obtained in later years, are of particular interest. Two went east and then south: two went west and one of these continued southwards down the west coast.

In the summer of 1921 a station, established on the north coast 45 miles west of Thurso at Talmine on the Kyle of Tongue (100 fish marked, 9 recaptured), dealt with very few fish of which a very small proportion were recaptured. But the interest of the results obtained was out of all proportion to the numbers. Of one hundred fish marked and nine recaptured (Figure 8) only three were found within 30 miles of the place of marking: two of these were taken in the Hope district, which is the first river to the westward round Whiten Head, and some fifteen miles from Talmine; and the other was found in the Halladale, some twenty-five miles east of the Kyle of Tongue. Of the other six, four had gone westward to Cape Wrath, and then some considerable distance to the south. One of the four completed at least sixty-four miles in all to Clachtoll, a bag-net station a few miles to the north of Lochinver. Another travelled eighty-six miles to Gruinard Bay, and the third was found at Badentarbert, on the northern side of the entrance to Loch Broom, eighty miles from our nets. The fourth fish, which had moved west, avoided all coast nets, and was not found until caught on the rod, when a kelt, in Loch Clair at the head of the Ewe district, in April 1922, eleven months after it was marked. This was a greater traveller than any of the others, as it covered at least 120 miles. Of the eastward journeys one to the Halladale has already been

0
50
100 Miles
SOGNEFJORD, NORWAY
LOCH INCHARD
L. HOPE
R. NAVER
R. HALLADALE
R. THURSO
WICK
DUNBEATH
R. HELMSDALE
LEWIS
RHU STOER
LOCH SHIN
LOCH BROOM
R. OYKELL
RUDH RE
R. CONON
R. SPEY
PORTREE
SOAY
ABERDEEN

R. DEE
13.
MONTROSE
15.13.17
13
18.
R. TAY
39
MULL
R. FORTH
9
WHITBY
17
17
19
R. TWEED

Fig. 9

mentioned. Two other salmon swam past the north-ast point of the mainland of Scotland, and con-nued south. One, after travelling 140 miles, was etaken at Cromarty, but the other was not found ntil it had reached the Avon, a tributary of the pey, some twenty-seven miles from the mouth of ne river. If this latter fish moved parallel with ne coast line for the major part of the way, the ourney between the time of marking and the time f recapture was one of some 240 miles.

Subsequent to 1921 a long gap existed before was possible to resume this work in 1936 on the est coast at Loch Inchard (1255 fish marked, 2 per cent. recaptured) which is some twelve iles south of Cape Wrath and round the corner s it were from the Kyle of Tongue. Here netting onditions were the same as at the Kyle of Tongue. hey were different from those at Thurso Bay and till more different from the conditions in the arlier years when the work was carried out in the Moray Firth. Along the whole of the Moray Firth oasts fixed nets are numerous and sweep nets are orked for the greater part of the legal season in ne lower waters of many of the rivers. Near hurso fixed nets are worked to the westward but re not so numerous as in the Moray Firth; sweep ets are also not worked so intensively. Near the yle of Tongue and Loch Inchard sweep nets are ot used, fixed nets are absent on the north coast the west of Strathy Point (see Figure 4) and re not found on the west coast until Rhu Stoer s reached (thirty miles from Cape Wrath). From is last point southwards, however, they are oderately numerous down to, and including, the orth-east coast of Skye, although they are absent rom the islands on the western side af the Minch. One consequently could not expect to find a con-entration of recaptures along the coast within a imited distance of the place of marking. Yet at he same time the absence of nets cannot be held to ncourage the capture of fish at a distance by the limination of the possibility of capture near the lace of marking. The Thurso Bay fish, for nstance, had ample opportunity of moving right way from that area during the long dry period f 1920 just as the East Sutherland fish in 1915 ad more than adequate room and opportunity for aking long journeys from the considerable stretch f coast (25 miles) entirely without nets to both orth and south of the place of marking. The bsence of nets in 1936 precluded recaptures along he coast within twenty miles to the south and about orty-five miles to the north and east of the place f marking. Recaptures made in our own nets, in he first bag net station (on north side of Rhu toer) to the south and in the first two rivers of he north coast suggest that had nets been set a ertain number of fish would have been caught in he area, say twenty miles in extent in either irection, just as recaptures were made round the laces of marking in the Moray Firth. The indications are, however, that the incidence of recapture would not have been high.

But in addition to these purely local movements of the local stock, for which there is ample precedent in the earlier experiments, we found from Loch Inchard a very extensive move on the part of many of the recaptured fish the possibility of which had been indicated at the Kyle of Tongue. In this year the long range migrations embraced not merely a few fish but included the majority of those which were again reported. Of the 34 fish recaptured in 1913 79 per cent. were found within 25 miles of the place of marking and for 1915 and for 1920 (Thurso Bay) the relative figures were 76 and 97 per cent. respectively. Now in 1936 if we extend the first area to fifty miles on either side of Loch Inchard we find that only fifty-one out of one hundred and forty seven fish were there taken and that, therefore, 65 per cent. were recaptured outside an area which is twice as long in each direction as that used for the earlier stations. In point of fact the journeys undertaken (Figure 9) extended to the Sognefjord, Norway (400 miles), and Whitby on the Yorkshire coast in the north-east of England (410 miles). Many of the nearer fish were necessarily found in rivers and some of those which went for a much longer distance were similarly recovered in fresh water, e.g., rivers Shin (180 miles), Conon (160 miles), Spey (145 miles), Tay (290 miles), Forth (300 miles), Tweed (300 miles). Those that were not actually in fresh water were often grouped in nets set close to the mouths of certain rivers, e.g., Naver (40 miles, 6 fish), Halladale (52 miles, 28 fish), Forrs (64 miles, 5 fish), Thurso (70 miles, 24 fish). Five fish taken in the bag nets of the east coast of Caithness occupied positions known from our work in 1915 to be frequented during dry weather by salmon from the rivers Brora and Helmsdale: single fish taken in the Moray Firth near the Spey and on either side of Aberdeen (200 miles) and five caught near Montrose (230 miles) may belong to one or other of the rivers of the part of the coast concerned or when finally captured may have been occupied in a still longer journey. The movements and destination of the fish on the coasts south of Buchan Ness, and particularly that part near Montrose, require investigation and elucidation before anything can be said as to the lines of migration and origin of the fish caught here. Further south the fish in Tay and Forth and Tweed, and the last caught by a drift net off Whitby (410 miles) have already been noted: like those of the Aberdeen and Montrose coast this, the Whitby fish, belongs to an unknown river.

On the west coast the fish are less markedly grouped round the rivers but the nets are not so set as to bring out this particular arrangement even if it does exist. Some are found actually in the nearer rivers, e.g., Cannaird (47 miles), Broom

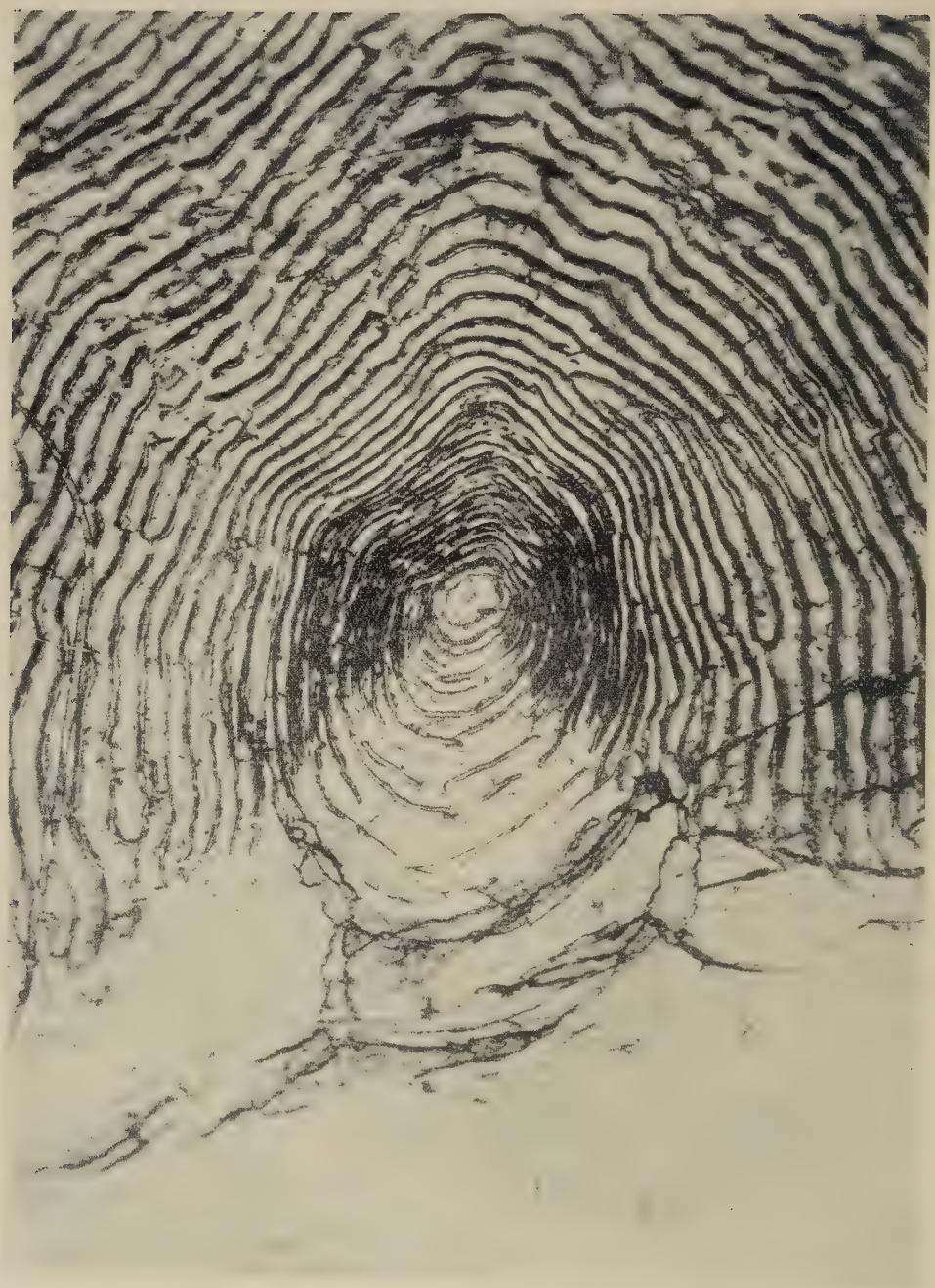


Plate I
5½ lbs; 63 cm; marked Loch Inchard 8/6/36: Recaptured Sognefjord, Norway, 29/7/36: 2·1+
(Part of adult fish scale).

(55 miles), Ewe (53 miles) and three in rivers of Lewis, viz., Soval (57 miles), Grimersta (75 miles). In the bag nets they were found on the east side of Skye (80 miles, 4 fish), on the island of Soay (130 miles), Loch Nevis (117 miles) and down to the north of Mull (150 miles).

Scales from recaptured fish indicated that those caught in, or at the mouth of, various rivers had the parr areas of their scales similar to the parr scale area of fish known to be native of those rivers. So distinctive is the parr scale growth that these scales show without possibility of doubt that

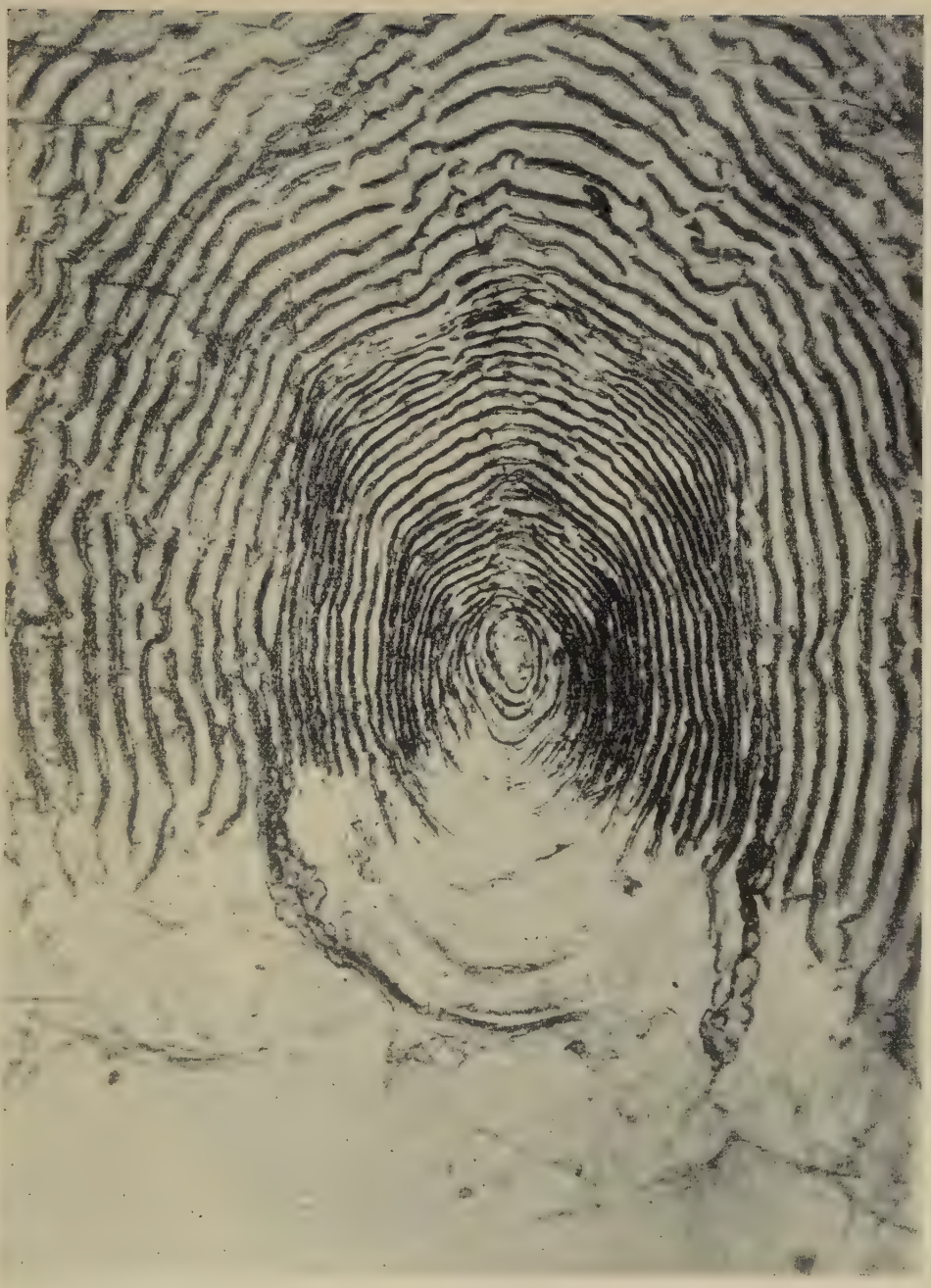


Plate II, a
5 lb. 10 ozs; 66¼ cm.; marked Loch Inchard 6/7/36: Recaptured Tweed, 23/7/36: 2·1+
(Part of adult fish scale).

e fish in question had not made a chance journey an unparticularised destination but had made a finite migration back to the river from which they iginally descended as smolts. This differentiation the parr growth is also well shown in the scales the fish which was recaught at Sognefjord and which had a parr area (Plate I) typical of that of Norwegian salmon in general and quite unlike that of Scottish rivers. The Tweed recapture on the other hand had scales of a very rapid growth-type which is quite different from the type of other east coast rivers. A photograph of the scales

Plate II, b
Tweed two-years-old smolt. (Part of adult fish scale).

is given in Plate II a together with (Plate II b) the parr area of a typical Tweed salmon scale of the same (two years) smolt age.

This homing instinct is further borne out by scales from three salmon, sent to me by Professor Knut Dahl, marked in Norway and recaptured in Scotland. One of these taken in a coast net at Montrose was of a general east coast type and could not be allocated to any particular river: it might have been a native of the South or North Esk or the Don, it certainly did not belong to Dee, Forth or Tweed. The Forth parr scales are particularly well "marked" by a small first, and a large second, year's growth; the marked fish caught in that river reproduced exactly this type of growth (Plate III a b and c). In the Tweed parr growth throughout life is exceptionally good and this again is exemplified in the fish caught there (Plate IV) which as a smolt was only one year old.

The results of this Loch Inchard experiment are in striking contrast to those of earlier years. The majority of fish have not remained near the place of marking but have made considerable journeys. Although the marking station was on the west coast only one fish was recaught on that coast for every three that were caught on the north and east coasts. It would appear that many fish strike in to this part of the coast when on their way back from the feeding grounds but when still a considerable distance from their own rivers, and that the fish belonging to the nearer rivers form only a relatively small proportion of the total.

To test the 1936 results the experimental station was moved only twenty miles south of Loch Inchard in 1937 and at Raffin (448 fish marked, 13 per cent. recaptured) just to the south of Rhu Stoer, it was approximately half-way down the Minch (Figure 10). This situation, however, did not reveal a different run of salmon. The results obtained practically duplicated those of the previous year, the only change being a slightly higher proportion of fish of west coast origin. On this occasion the nets were set between two commercial bag-net stations and any fish migrating southwards were immediately faced with a succession of stations down to, and including, the Island of Skye, but the shore to the north and at the west end of the north coast was again clear of nets.

L. Inchard
L. Hope
R. Naver
R. Helmsdale
R. Thurso
WICK
DUNBEATH
Rafflin
NETS
Culkein
Loch Broom H.
Tarbat Ness
Lewis
L. Torridon
Loch Sligachan
Portree
SKYE
R. Findhorn
R. Spey
ABERDEEN
MONTROSE
R. Tay
10 0
50 Miles

Fig. 10

Plate III, a
5½ lbs; 27 ins; marked at Melvaer off Sognefjord 10/7/37; recaptured River Forth 5/8/37.

Experience gained in the Moray Firth and at urso would suggest that a considerable pro- rtion of the marked fish which belonged to ers within at least fifteen or twenty miles of place of marking would be caught in the mmercial nets which were set to the south of Rhu er. None of the rivers of this part of the west st are comparable to the larger and more im- rtant salmon rivers of the east coast but some, , Laxford, Inver, Ullapool, Ewe hold a quantity salmon which is limited only by the size of the ers and the extent and quality of the available spawning ground. The recaptures made in these nets are in consonance with these facts in that a few marked fish were caught all the way down to Skye. The number so caught — 21 fish — (36 $^0/_0$ of all recaptures) was not great but is not out of proportion to the known stocks of the various districts. No great aggregation of recaptures such as was experienced in earlier years could be expected and, if such had actually occurred, then it would be clear that fish of only local origin could not be involved.

The Loch Inchard nets in 1936 were really

Plate III, b.
9 lbs; 76 cm; 29/4/21; Typical Forth fish; 2·2.

within the local cruising range of salmon from the Laxford and a few minor streams on the west coast. The Rhu Stoer station is still within the radius of movement of the Laxford fish but in addition it is within the area of those from the Inver, Kirkaig, Ullapool and Broom. Consequently a greater proportion of fish of these rivers might be anticipated at Rhu Stoer than at Loch Inchard. This anticipation was realised: as already stated from Loc Inchard three fish went north and east for eve one that went south while now from Rhu Sto three salmon are found to go north and east f every two that remain on the west coast.

The west coast recaptures in 1937 were scatter all the way down to Skye and then an isolated fi near the south end of Mull. None of the mark

Plate III, c.
6½ lbs; 62½ cm.; Marked Loch Inchard 1/7/36; recaptured Forth 10/7/36.

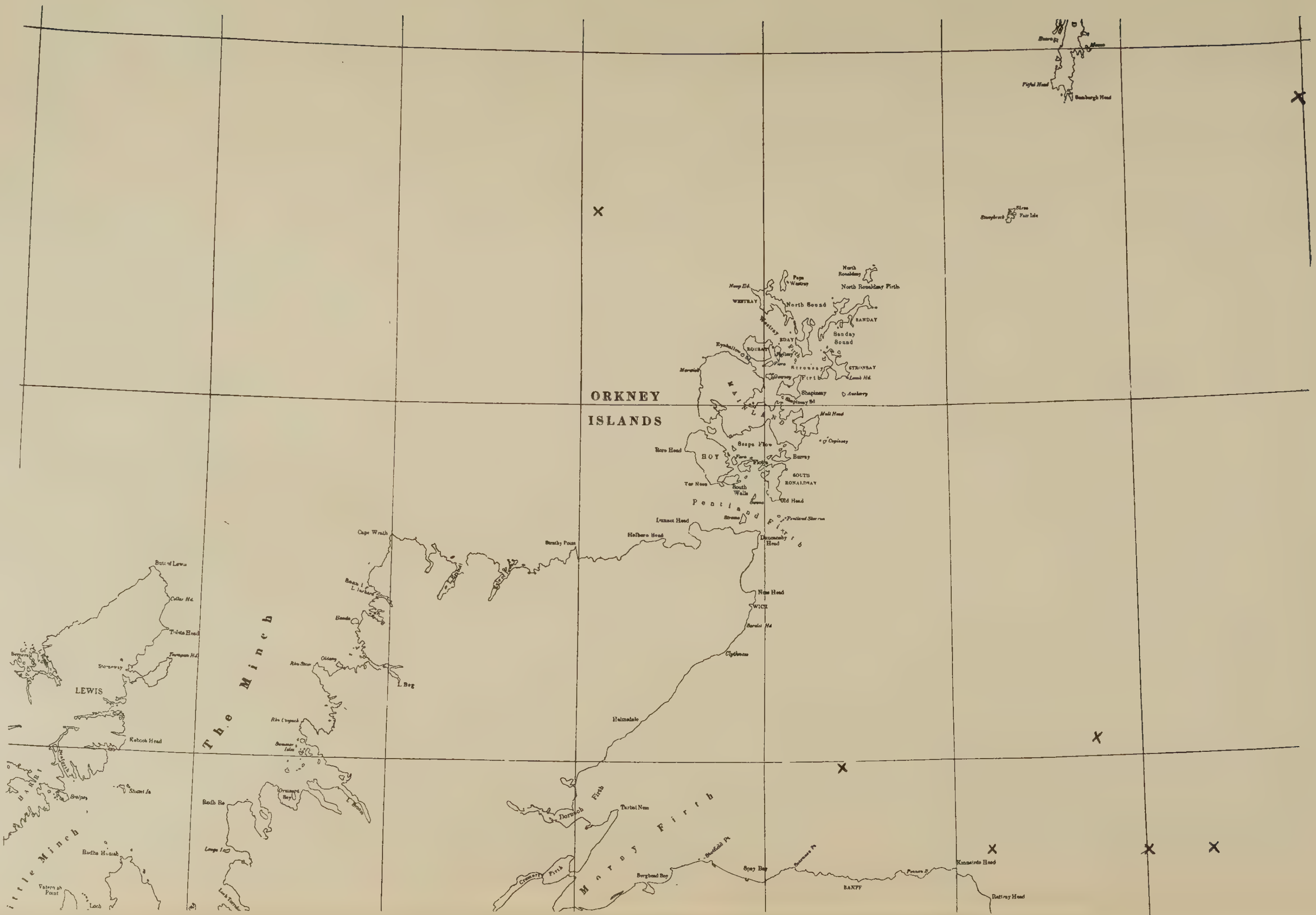
went to Norway and as the others were grouped very similar fashion to those of 1936 it is ely necessary to recapitulate the details here: will be found on the map on Figure 10. It is cient to note that on the east coast the most erly salmon was found in the Forth and that a rout, marked at Rhu Stoer, was netted in the d. This last is of particular interest since the sea growth of the Tweed trout is much more rapid than that of any other sea trout in Scotland and, so far as is known, in Great Britain is only equalled by the growth of the trout from the neighbouring rivers Aln and Coquet. The marked trout weighed 8½ lbs. and was 71 cm. long, but had spent only 1+ years feeding in the sea: knowing its size and age one could say with

Plate IV.
4 lbs. 24 ins; marked Melvaer off Sognefjord 11/7/37; recaptured Tweed 9/8/37.
(Part of adult fish scale).

certainty that it could belong only to Tweed, Aln or Coquet.

Summarised shortly the 1937 results confirm those of 1936 and show that the majority of fish on the coast even thirty miles south of Cape Wrath belong to north and east coast rivers and that only a minority belong to the west coast with compar tively few native of the rivers near (within thir miles) of the place of marking.

In supplement of these definite records marked salmon we have information regarding t capture of a certain number of salmon by trawle


ORKNEY
ISLANDS
North Ronaldsay Firth
North Sound
SANDAY
Sanday Sound
STRONSAY
Shapinsay
WESTRAY
HOY
Scapa Flow
Burray
SOUTH RONALDSAY
Pentland Firth
South Walls
Old Head
Duncansby Head
Noss Head
WICK
Cape Wrath
Strathy Point
Holborn Head
L. Beg
LEWIS
Butt of Lewis
Tiumpan Hd.
Kebock Head
The Minch
Moray Firth
Dornoch Firth
Tarbat Ness
Cromarty Firth
Burghead Bay
Spey Bay
BANFF
Kinnairds Head
Rattray Head
Sumburgh Head
Fitful Head
Fair Isle
Helmsdale
Clythness
Tor Ness
Barra Head
Copinsay
Auskerry
Papa Westray
North Ronaldsay

L. Shieldaig
Applecross B
Mooness B.
Idrigill Pt.
ISLAND OF SKYE
Inner Sound
Sea of the ebrides
Soay
Canna
Sound of Canna
RUM
Sound of Sleat
Eigg
Muck
L. Ailort
Point of Ardnamurchan
COLL
Loch Linnhe
ISLAND OF MULL
Oban
Staffa
Iona
Firth of Lorne
Scarba
COLONSAY
Oronsay
JURA
Sound of Jura
ISLAY
ABERDEEN
Peterhead
Buchan Ness
Girdle Ness
STONEHAVEN
Tod Hd.
Montrose
Scurdy Ness
Red Hd.
Arbroath
Inchcape or Bell Rock
PERTH
Firth of Tay
St. Andrew's Bay
Fife Ness
Kirkcaldy
Firth of Forth
Gullane Ness
N. Berwick
Dunbar
St. Abb's Head
GLASGOW

Fig. 11

orking out at sea. Such records, however, are ecessarily extremely fragmentary and are spread ver a long period (from 1890): for some years a pecial enquiry has been made for such captures ut, rare as they are, it is probable that not all ave been reported partly owing to lack of know-edge on the part of the captor of the request for he information and partly because an impression xists that the capture of the fish is illegal — so uch is the latter the case that the salmon are lmost invariably eaten on board the trawler and re not landed for the market.

For what they are worth the areas where aptures have been reported are shown in Figure 11. he positions indicated follow roughly a line drawn p to thirty or forty miles off shore from the hetland Islands down to the Dogger Bank area. o concentration at any particular point is shown or is any route of migration demonstrated. The nly interpretation that can be placed on the result that it represents a chance capture of the fish hile on their way to or from their feeding grounds ith origin probably in the east coast rivers of cotland although possibly they might belong to vers of England or the continent.

Such then is the evidence in detail of the move-ents of salmon along the coasts of the northern art of Scotland. It now remains to consider the mplications which it carries and the broad lines f interpretation which it allows.

First of all we have to consider if the salmon as, at any time or at all times, inshore feeding rounds or if it feeds at considerable distances from e coast. There can be no doubt that the salmon e are now dealing with, and all those taken at mmercial fisheries on the coasts of Scotland, are n their way from their feeding grounds to fresh ater when they are netted. Occasionally remains f food may be found in the intestine, very rarely od may be found in the stomach but in general omach and intestine are empty, the feeding period finished and the fasting ante-spawning period as commenced. Even if the fish be retained by hysical conditions in the sea long after they desire enter fresh water, as in Thurso Bay in 1920, eding is not recommenced. If retained long ough in the sea the salmon begin to lose weight d become red. In all the marking experiments t a single marked fish which has not shown ite unmistakeable evidence of having spawned the interval has been recaptured in a year llowing that of marking.

If salmon frequented inshore feeding grounds ey would be caught on baited lines as they are ught in the Baltic or they would be taken by ine or trawl nets as soon as they were large ough to be retained by the meshes of the net. If ey adopted a pelagic life when feeding they uld inevitably be taken in the first spring and mmer of their marine life in herring nets just as a trout at the same stage of life are taken from the Moray Firth to the Firth of Forth and off the middle west coast of Scotland also. But in spite of the intensive fishing of all kinds off the British coasts salmon are never caught in such quantities or at such stages of their life as to suggest anything like a congregation of growing fish gathered together in a selected feeding area.

No reason exists for believing that the fish which are recorded on the chart on Figure 11 were not all either adult fish on their way to fresh water or, in a very few instances, kelts returning to sea: no evidence of recent feeding was obtained in such stomachs as were examined. They are spread out over a very wide area, they were caught over a large number of months in the year and nothing suggests a particular congregation at a particular place at any particular season of the year. Even the smolts directly they leave the rivers are never taken except when they are found in such predatory enemies as saithe and conger eels. We are forced to the conclusion that once smolts or kelts reach salt water they move off without hesitation to a feeding ground at some considerable distance from their point of departure. Professor D a h l found the smolt beginning to feed and grow off the Norwegian coast. We have no evidence of a like happening off the Scottish coasts and indeed it is possible that some of Professor D a h l's fish were of Scottish origin on their way north. That feeding grounds for British salmon is in the North Sea seems to be impossible. Were it anywhere in this intensively fished area the record of captures made by trawlers, and in herring drift nets, must have been infinitely greater during the last forty years than has actually been the case. Large sea trout of a size comparable with that of smaller salmon are known to feed on the coasts of Denmark and Holland and on the southern half of the English coast. They are caught in all these areas. One can only presume that food adequate for these sea trout would be equally acceptable to salmon of the same size and as illustrative of the absence of feeding by salmon one has only to record the absence of this species from these areas.

We may thus exclude the North Sea as a feeding ground for Scottish, or indeed any, salmon. We have still to decide where they go, whether they frequent one area or several feeding areas and the light which the marking of salmon on the Scottish coast may shed on these questions.

We may first consider whether it is probable that the salmon of the rivers of the continent, of the east and west sides respectively of Great Britain, and of Ireland all go to the same food source or whether they frequent different areas perhaps relatively adjacent to each other or possibly separated by large ocean spaces. It seems a little difficult to believe that the salmon of, for instance, the south-west of England and the south of Ireland can have the same feeding places as those originating from the rivers of the Moray

Firth, the south-east of Scotland or of Norway. Scale investigations in Scotland have also shown that the salmon of the rivers of the west coast, when all conditions are equal for both, make a definitely greater increase in length in their first year in the sea than do those from rivers of the east coast. The grilse of the east coast are earlier than those of the west coast, and at the same dates the west coast grilse are larger than those on the east coast. It might be said that this results from a difference in the primary size of the smolts or that these are hereditary characters which are developed by the fish from the two sides of Scotland even if they are feeding and growing in the same environment. The only growth characteristic common to individual rivers on each side of Scotland is produced by the original smolt length. The sea growth responds to the smolt growth and the longer smolt invariably produces the greater length at the end of any year of sea life. When we have this feature as between fish of adjoining rivers it seems impossible, if the fish of the two coasts of Scotland were feeding side by side, that they should develop an altogether separate growth characteristic. If they were so feeding the only factor which would produce a difference in the average length at the end of the first year in the sea would be a difference in the average smolt lengths. For the west coast salmon to be longer, the west coast smolts would have to be longer. Whereas the west coast smolts are not longer than those of the east coast and indeed in certain rivers the reverse may be the case. The grilse of the Forth and Tweed are larger than those of other east coast rivers, but their larger size is a factor directly connected with the time of their return (which is a month later than the average) and the extra feeding they are able to enjoy. But the larger size of the west coast grilse cannot be accounted for in similar fashion since they are longer than the east coast grilse at the common time of the end of their first year of sea life and are always larger if west and east coast grilse taken at the same dates be compared. This variation in the size of the grilse from the two sides of the country can be used as a check on the origin of the grilse which were marked in 1936 and 1937. If the movements represent a definite homing migration and are not merely erratic wanderings then those retaken on the west and east coast respectively should conform to the rule which has been deduced from the independent examination of scales from rivers from each side of the country. The particulars are as follows: —

	Length at end of 1st year in Sea		Size.			
	West	East.	West		East.	
	cm.	cm.	Wgt. lbs,	Lgth. cm.	Wgt. lbs.	Lgth. cm.
1936 Loch Inchard.	50·	49·	6·6	67·	5·5	63·
1937 Rhu Stoer. . .	46·5	43·5	6·2	65·5	4·2	57·5

These figures amply confirm the evidence already obtained from the examination of the parr areas of the scales and show that the fish concerned conform with the known characteristics of the salmon of the coasts of Scotland to which they travelled. In explanation of the variation in size as between 1936 and 1937 it should be added that the grilse of 1936 throughout Scotland were about one pound heavier than normally.

These facts would suggest that at least two separate feeding areas do exist even for salmon from such comparatively adjacent districts as the east and west Scottish coasts. How the salmon of the rivers of the north coast fit into this division has not yet been ascertained. I cannot, of course, speak of Norwegian or other continental salmon.

At first it would seem to be difficult to reconcile this separation of the feeding grounds with the arrival of fish belonging to both coasts simultaneously at one point such as Loch Inchard or Rhu Stoer. But this difficulty is not as insuperable as it seems since it is quite possible that in this area at the north end of the Minch salmon may strike in from the north or north-west and at the same time others may be diverted to the same destination from feeding grounds further to the south, and possibly further to the west also, by the imposition of the barrier formed by the outer Hebrides from Barra up to the Butt of Lewis.

In order to consider the matter further it will now be most convenient to link together the various parts and stages of the marking programme during which 5073 salmon have been marked in the sea and 20 per cent. of these have been recaught. To do this to best advantage it will be most suitable to consider first the results obtained on the north-west and north coasts and then the earlier returns on the east coast.

If the feeding ground of the east coast fish lie immediately to the westward, or to the south of westward, of Scotland then the Shetland—Orkney line of islands must inevitably exercise a very definite, and controlling, influence on the run. The fish must be shepherded to the north of Shetland or through the Fair Isle channel or through Pentland Firth. If large numbers came through by this last route then not only would commercial stations on the shores in the vicinity be very remunerative but also large numbers would be seen round the Shetland and Orkney Islands in the summer and many would turn into Thurso Bay. Our marking experiments in the last named area would have demonstrated their presence and the sight of fish jumping round and among the islands would have been reported. In point of fact fish are not seen round the island shores and the Thurso Bay marking produced no evidence at all of any dominant migration eastwards. Nor are the commercial nets on the eastern half of the north coast unusually plentiful or unusually successful. A westerly feeding ground would also cause many of the fish to come in south of Barra or through one of the sounds in the Outer Hebrides. This

would result in a congregation of salmon in the Minch of which the commercial netting along its shores gives no sign. Any considerable quantity of salmon passing close to the land or in narrow channels of the outer islands, in the summer time when they show themselves freely, must inevitably have been noticed here as it would have been in Shetland and Orkney, by those frequenting the coasts. They are never seen and on all counts a westerly feeding ground would, therefore, appear to be improbable.

The same arguments as well as those suggesting captures during the feeding period apply against a feeding ground only slightly to the north of Scotland. We are driven to the conclusion that the salmon must arrive from some considerable distance to the north or north-west, and probably the latter, of the British Isles. From this area the Shetland—Orkney line would still provide an important factor but it would divide the fish more surely in the general direction of their destination. If anywhere on the borderline they would be more likely to take the correct side of the land or proceed eastwards through the Fair Isle channel and east coast salmon would not be concentrated at the easterly end of the north coast. At the same time such division cannot be perfect, especially if fish came from far to the westward, say in the general direction of Iceland, and the outer edges of the fan shaped (as one must suppose it) wave of migration to the east coast may quite readily and naturally reach the western end of the north coast and the northern end of the west coast. It is equally possible that salmon belonging to rivers of the north and west coasts should make at landfall at the east end of the north coast or pass eastwards of the Shetland—Orkney group and then re-set their course. A very few recaptures of marked clean fish support this possibility and we have certain examples of west coast fish on the north coast, as for instance one clean fish from Thurso Bay as well as kelts marked in the Barvas and Grimersta (west side of Lewis) which were recaptured when again clean fish in Thurso Bay and the Carron kelt recaptured at Melvich.

Supposing this far north-westerly origin one may anticipate that the vast majority of salmon destined for east coast rivers would set a sufficiently accurate course to pass to the east of the Shetland—Orkney line. When one looks at the chart it is less surprising that some should touch the Norwegian coast before reaching Scotland, as Professor D a h l's work has shown to be the case, than that others should be as far west as Cape Wrath. That five recaptures have been made in Scotland from the limited number of salmon marked at the Sognefjord suggests that a far higher proportion move in this direction than by the westerly route.

We are not yet in a position even to make a surmise as to where a separate feeding ground for salmon from west coast rivers may be. It is hoped that it may be possible to mark salmon this year on the west coast at a position to the south of Skye. Results from here may shed some light on the problem.

Once within the confines of the North Sea it would appear that the fish move southwards clear of the coast and only approach close inshore when relatively near their own rivers. Commercial netting results, however, suggest that there may be a few centres where fish strike the coast far from their own rivers and then re-distribute themselves. Such points are possibly near Tarbet Ness, to the south of Aberdeen and near Montrose but no work has yet been done to elucidate the questions which arise at these points. Our own marking results show that within the confines of the Moray Firth there is only a limited movement, towards the rivers, which may be roughly in the general direction of the prevailing eddy tide running inwards from Burghead and then upwards along the Ross and Sutherland coast. It is quite possible, however, that there are two lines of approach to these Moray Firth rivers, the one direct from the north or through the Pentland Firth and the other from southwards by fish which have come down the centre of the North Sea and have then turned in, somewhat late, towards the coast and their own waterways. Such a possibility is supported by the recaptures of kelts marked in the Helmsdale and referred to on page 19. Very few fish natives of rivers further south penetrate into the inner part of the Moray Firth. It is possible that these are fish which have approached through the Pentland Firth and thereafter are clinging more closely to the coast than do those which come down through the main Shetland—Norway channel.

Bibliography.

The following papers in the *Fisheries, Scotland, Salmon Fisheries* series of the Fishery Board for Scotland:—

C a l d e r w o o d, W. L.
Sea Netting Results, 1913 No. I.
Sea Netting Results, 1914 No. III.
Sea Netting Results, 1915 No. I.
Sea Netting Results, 1920 No. I.
Results of Salmon and Sea Trout Marking in Sea and River, 1922, No. I.

M e n z i e s, W. J. M.
The Movements of Salmon Marked in the Sea, 1937 No. I.
The Movements of Salmon Marked in the Sea, 1938 No. I.